A QUASI-EXPERIMENTAL STUDY OF AN INTERVENTION USING THE TEXT STRUCTURE STRATEGY IN GRADE 7 SCIENCE

A Dissertation

by

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ABSTRACT

The ability to comprehend science texts is not only an academic skill but a life skill. Currently, however, the majority of students across grade levels in the United States are reading below grade level *and* have science achievement below grade level. The text structure strategy, a reading comprehension strategy in which students are taught to use the structure of a text (e.g., comparison, cause and effect, problem and solution) to construct the main idea of the text, has been shown to be successful in improving reading comprehension. Therefore, the text structure strategy was implemented in grade 7 science classes to improve reading comprehension and science knowledge. The intervention included practice-based professional development, weekly instructional planning, modeling of text structure lessons in science, and adaptation of instructional materials to support the text structure strategy.

This study investigated the efficacy of the text structure strategy in a grade 7 science classroom with four teachers and 169 students in a small, semi-rural district. The researcher collaborated with school administrators to provide teachers with practice-based professional development and ongoing in- and out-of-classroom support during the intervention. The study utilized a quasi-experimental pretest-posttest design. Results from paired *t*-tests showed that students significantly improved on science knowledge, reading comprehension, signaling word knowledge, and main idea quality. The text structure strategy in science has promise as an effective strategy to improve reading comprehension and science knowledge of middle school students.

DEDICATION

This dissertation is dedicated to my person and my little people. There are not words enough to express how much I love y'all. Thank you for supporting me on this journey.

This dissertation is also dedicated to my parents. My love of learning and asking questions is solidly built on a foundation developed with your love and support. Thanks for helping a stubborn opinionated girl become a determined knowledgeable woman.

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NOMENCLATURE

ELA	English Language Arts
GSRT	Gray Silent Reading Test
NAEP	National Assessment of Educational Progress
SKA	Science Knowledge Assessment
STAAR	State of Texas Assessments of Academic Readiness
TEA	Texas Education Agency
Text structure	The organizational structure used by an author (e.g., comparison, cause-and-effect, problem-and-solution, sequence, description)

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CHAPTER I

INTRODUCTION

Middle school students are struggling with science reading comprehension. On average one in four students have regularly failed the State of Texas Assessment of Academic Readiness (STAAR) 8th Grade Science test since its beginning in the 2012-2013 school year (Texas Education Agency (TEA), 2018). Additionally, national science achievement among grade 8 students is declining (National Assessment of Educational Progress (NAEP), 2015). Students do not currently possess the reading comprehension strategies needed to assist them *now* as they learn the science content presented in their classrooms and *later* as they need to use the language of science to live healthy and scientifically literate lives (i.e., the ability to understand scientific concepts needed for daily life). Understanding the language of science is not only helpful in learning new concepts, it is a *critical* part of science literacy (Lemke, 1990; Yore, Bisanz, & Hand, 2003). Norris and Phillips (2003) found that reading and writing have a constitutive relationship with science, meaning there is no science without reading and writing. O'Reilly and McNamara (2007) further explored the connection between reading and science and found that students with better reading comprehension were better able to compensate for low science knowledge than students with low reading comprehension. Lemke (1990) supports the reading science connection by suggesting that wording of science concepts may change from book to book or teacher to teacher, but that "the pattern of relationships of meaning, always stays the same" (p. x). Additionally, Yore et al. (2003) highlight that text structures, such as problem-and-solution and cause-and-effect, are linguistic devices used in scientific texts. Therefore, to help struggling students overcome their difficulty with science content area reading comprehension, this study implemented a text structure-based intervention designed to improve student science reading comprehension with a secondary aim of improving science content knowledge.

Literacy Issues Affecting Adolescent Readers

Consistently low literacy levels. The majority of students in grade 12 (63%) and grade 8 (66%) are reading at or below the basic reading level (NAEP, 2017). These numbers are significantly worse for Black and Hispanic students and students with disabilities (NAEP, 2017). According to The Nation's Report Card (2017) students performing at or below the basic level lack mastery of fundamental skills needed to perform at grade level. This means the majority of adolescents in the United States have reading skills considered below grade level and are likely to struggle with tasks such as making inferences, analyzing what was read, summarizing a text, and other higher-level skills needed for success in school and life. What is more troubling is since 1992 these numbers have remained relatively unchanged. This means for over two decades the majority of adolescents in the United States have been unable to read above a basic level and have entered the workforce or post-secondary education with reading skills far below what is needed for success. Foorman, Petscher, Stanley, Truckenmiller (2016) found similar struggles for students in grades 5 and 8. Conformity factor analysis of reading and language variables found 53% of fifth-grade students and 72% of eighth-grade students scored low on all variables (Foorman et al., 2016). Consistently low performance across multiple measures suggests that literacy practices at the middle school level are not functionally meeting the needs of the majority of students.

Low science scores. In addition to low reading ability, students are performing at critically low levels in science (NAEP, 2015). The majority of grade 8 students (66%) scored at or the below basic achievement level (NAEP, 2015). Scores for Black and Hispanic students are more troubling. Fewer than 20% of Black or Hispanic students achieved scores at proficient or above. These numbers create a troubling picture of our nation's current knowledge of science.

Scores on high-stakes science tests are also critically low. In Texas, 26% of students in grade 8 scored in the "did not meet grade level" performance standard category on the STAAR grade 8 science test for the main administration in the 2016-2017 school year. This means that one-in-four students were found to be "unlikely to succeed in the next grade or course without significant, ongoing academic intervention" (TEA, 2017) according to the STAAR performance label definition for "did not meet grade level". Additionally, students scoring in the "did not meet grade level" category "do not demonstrate a sufficient understanding of the assessed knowledge and skills" (TEA, 2017). The number of students scoring in the "did not meet grade level" category increases for Hispanic (31%) and African-American (38%) students. Almost half (44%) of at-risk students and 70% of students receiving special education services received a "did not meet grade level" score. Also troubling is STAAR pass rates have remained stagnant since the test's introduction in 2012 (TEA, 2018). Although the STAAR science test is presented as a measure of content knowledge, all questions require grade-appropriate levels of reading comprehension for students to understand the question being asked and to determine the correct answer. Additionally, students must be able to determine whether the question is asking them to perform tasks such as identify part of a cause-and-effect relationship or make a comparison between given data.

Issues in literacy instruction in middle school and the content areas. Literacy instruction at the middle school level greatly differs from instruction at the elementary level (Shanahan & Shanahan, 2008). In the middle grades, teaching is frequently departmentalized. This means that students have a different teacher for each subject. Additionally, middle school level content area teachers typically receive less pre-service training in reading than early childhood through grade 6 (EC-6) or middle school English Language Arts (ELA) teachers. In Texas, the reduced literacy training for content area teachers may be due to the lack of literacy standards tied to grades 6-8 science courses. Furthermore, mathematics is often suggested as the language of science through the focus on formulas and calculations rather than oral or written language (Hand et al., 2003; Yore et al. 2003). Despite lesson models such as the 5E model (engage, explore, explain, extend, and evaluate) that encourage hands-on activities to teach science concepts, students gain much of their information about science topics through *reading* (Kaldenberg, Watt, & Therrien, 2015; O'Reilly & McNamara, 2007).

Following Chall's (1983) stages of reading, see Table 1, middle school students should be at the end of stage three and moving through to stage four. In stage three, instruction focuses on introducing expository texts and strategies to extend reading comprehension. In stage four, students increase their expertise in using strategies and deepen knowledge in areas like text structures and features, genre, vocabulary, and other areas. Students at the middle school level are thus expected to apply their well-honed reading comprehension skills in not only their reading/ English Language Arts classrooms, but in their science and social studies classrooms as well.

Table 1
Chall's Stages of Reading Development

Stage	Skills Taught	Materials Used
Stage 0: Pre-reading Birth to age 6	Oral language development Letter names and sounds Phonological awareness	Picture books, alphabet books, engage in pretend/pseudo-reading, writing, and language play
Stage 1: Initial reading/ Decoding Grade 1	Basic phonics skills Six-syllable patters Commonly used irregular words Oral language development	Children's storybooks, basal readers, and trade books
Stage 2: confirmation and fluency Grade 2-3	Decoding Fluency Affixes and roots Analysis of multi-syllable words Background knowledge development	Children's storybooks, workbooks, basal readers and trade books, familiar fiction and nonfiction
Stage 3: Reading to learn Grades 4-8	Reading for meaning Expository text structures Reading strategies Background knowledge development	Children's literature, basal readers, workbooks, content-area textbooks, beginning reference materials, and Internet sources.
Stage 4: Multiple viewpoints Grades 9-12	Reading for meaning Inferential thinking Perspective Specialized vocabulary	Fiction and nonfiction, reference materials, newspapers, magazines, and Internet sources
Stage 5: Construction and reconstruction College	Verbal reasoning Inferential thinking Author's perspective Analysis of genres	Fiction and nonfiction, periodicals, journals, and Internet sources.

Adapted from Farrall, M.L. (2012)

Middle school students are expected to be solidly in the reading to learn phase, having mastered the learning to read phase in lower grades. Yet, based on NAEP (2017) data there is a problem with this expectation. The majority of middle school students are struggling with their reading ability and need help (NAEP, 2017). Frequently, assistance for these students is offered through an elective reading class or a regular ELA class purposefully populated with struggling readers (Swanson, Wanzek, Vaughn, Roberts, & Fall, 2015). However, the majority of students with learning disabilities spend 80% of their time in the general education classroom, most frequently science and social studies class (Aud et al., 2010). A drawback of struggling students spending time in general education content area classes is the limited help offered in these classes with regard to improving reading comprehension in these areas. This is a problem because as Kaldenberg et al. (2015) point out, despite a shift towards hands-on learning, students are still expected to gain most science knowledge through expository texts.

Compounding the problem for content area teachers and struggling students is the variety of reading struggles students face (Swanson et al., 2015). Students may struggle with decoding, vocabulary, fluency, and background knowledge deficits, all of which affect reading comprehension (Swanson et al., 2015). Gersten, Fuchs, Williams, and Baker (2001) suggest that students with learning disabilities are able to identify when they do not understand what they read, but they are not able to use strategies effectively to fix the problem. Students need specific reading strategy instruction to target their difficulties so that students can automatize these strategies and have them available when texts become difficult (Cantrell, Almasi, Carter, Rintamaa, & Madded, 2010). However, students being able to use multiple strategies is not the end goal. The end goal is that students become strategic readers. Strategic readers think about the reading context and are efficiently and effectively able to apply the best strategies based on the context.

The need for changes in content literacy instruction. Reading comprehension of middle school science texts is especially critical. The topics covered in grades 6-8 science courses provide students with basic and functional science knowledge necessary to have a healthy life (Berkman et al., 2004; TEA, 2011), understand their environment (TEA, 2011), and be good stewards of the earth (TEA, 2011). It is therefore imperative that students be able to comprehend and later recall the information they gain in these courses not only to pass high stakes tests but to live scientifically literate lives.

Additionally, several researchers (Anderson, 1999; Hand et al. 2003; Lemke, 1990; Norris & Phillips, 2003, Yore et al., 2003) argue that text is actually the system most used by scientists to complete science tasks and that science literacy requires being able to read and write in the language of science. Lemke (1990) argues that the language used in science is a result of the members of the science community agreeing on a set way of communicating about science. However, students are not yet fluent in the communication processes and patterns used in science. This lack of fluency in the language of science means that students are in critical need of reading comprehension strategies that will help them develop both fundamental and derived science literacies needed for the immediate need of learning science concepts in the classroom and the lifelong need of being able to converse knowledgeably about science topics.

As stated previously, many students struggle with decoding and vocabulary deficits even at the middle school level. Poor decoding skills place additional strain on working memory needed for constructing meaning and monitoring reading comprehension (Baker, DeWyngaert, & Zeliger-Kandasamy, 2015). Nevertheless, fluent reading alone is not enough for full reading comprehension. It is common for a teacher to be surprised that a student, who appears to be a good reader, because they can decode grade-level words, does not comprehend what is read (Cartwright, 2015). Research has shown that better readers have better reading comprehension monitoring or metacognitive awareness than weaker readers and that these skills do not automatically improve as students get older and read more (Baker et al., 2015). Decoding and vocabulary interventions alone are not enough to help students improve reading comprehension.

In fact, over a twenty years ago, Pressley and Wharton-McDonald (1997) expressed concerns about attention being paid to word-level processing at the cost of text comprehension. Students need specific reading comprehension/metacognition instruction to improve reading comprehension. As mentioned previously, content area teachers may not possess the knowledge to provide this type of instruction. Authentic texts are rarely, if ever, transparent about the structure of ideas. Students must make inferences about how words, sentences, paragraphs, and longer chunks of texts are connected and how that relates to the main idea (Baker et al., 2015). Further, Pressley and Wharton-McDonald (1997) argue that good readers deliberately look for connections between different parts of a text and attempt to integrate those into a whole, sometimes using the connections to make inferences that fill in gaps in the text. However, struggling students do not develop strategies that help them make these connections without instruction (Pressley & Wharton-McDonald, 1997). The text structure strategy can help students improve in making these connections and inferences by providing explicit instruction to improve reading comprehension.

Reading is a critical lifelong skill, not simply a tool used to pass tests. The ability to comprehend what is read is needed to correctly take medicine, compare insurance policies, evaluate political candidates, and a host of other day-to-day tasks. Reading comprehension is then not only a literacy skill but also a life skill. Content areas, such as science, provide students with information and skills critical for full participation in adult life. The sharing of scientific knowledge is a social practice done through text and reading (Hand et al. 2003; Lemke, 1990). The dependence of science on sharing ideas via text also means that individuals with poor reading comprehension are also limited in their ability to gain science knowledge (Norris & Phillips, 2003). Without the ability to comprehend scientific texts and then interpret and evaluate the claims within them, students will be limited in their ability to learn how to best care for an ailing pet, increase the yield of their tomato plants, or limit the potential healthcare costs of a society that eats more and moves less. To ensure that adolescents are leaving the K-12 environment fully armed with the skills needed to be successful citizens, educators must reevaluate how reading comprehension is addressed in the middle grades and the content areas.

To address the previously discussed issues, this dissertation study used the text structure strategy to provide an intervention designed to improve middle-grade students' reading comprehension and recall of science content-area text. The theoretical foundation for this study comes from the text structure work of Bonnie Meyer (Meyer, 1975) which has seen positive results with students in grades 4-7 (Meyer et al., 2002; 2010; Meyer, Wijekumar, & Lin, 2011; Wijekumar, Meyer, & Lei, 2017; Wijekumar et al., 2017). Although these studies have used expository texts, they have done so in the English Language Arts classroom. This study sought to improve reading comprehension of science texts by focusing on reading instruction in the science classroom.

Research Questions

This dissertation study addresses three factors in student reading comprehension of science texts: 1) knowledge of text structures and signaling words, 2) competency in using signaling words and text structures to aid in reading comprehension, and 3) disciplinary (i.e., science) literacy.

This study aimed to evaluate the effectiveness of a text structure strategy-based intervention within the context of middle school science courses. The study sought to answer one main question:

1. Were there pre-posttest improvements in science and reading comprehension scores for seventh-grade students using the text structure strategy for 10 weeks?

This study also sought to answer three secondary questions:

2. Were there differences in improvements based on gender, ethnicity, economic status, and/or language proficiency?
3. Were there any teacher effects on student learning outcomes (e.g., Did student performance differ by science teacher?)
4. Do students with lower pretest science scores (i.e., raw score below 12 or 41%) demonstrate better improvements after intervention than those with higher pretest scores?

CHAPTER II

LITERATURE REVIEW

In the introduction, I outlined the problems facing students in regards to reading comprehension and content literacy with science. In this section, I will review the literature relating to the theoretical framework for the study, present the literature relating to content area literacy interventions for science, synthesize the literature on teacher influence of content literacy practices, and identify the gaps in the current literature, see Table A-1 in the Appendix for research design, population, measures, duration and conditions, and results of included studies.

Review of Theoretical Framework

The text structure strategy. The theoretical framework for this study has its roots in what Meyer, Brandt, and Bluth (1980) refer to as the text structure model. The text structure strategy stems from research showing that information presented higher in the content structure of a text is connected to better recall than information presented lower in the content structure (Meyer, 1975). For example, a science textbook passage comparing three of Earth's biomes in terms of climate, animals, and plants the information higher in the content structure would be the comparison of climate, animals, and plants. Information lower in the context structure would be the causes and effects of how the plants or animals have adapted to the climate.

The text structure strategy is the use of the content structure of a text to organize information in the memory, which in return helps with recall (Meyer et al., 1980). Additionally, the use of the text structure strategy without prior instruction has been found to be used by those with good reading comprehension, while those with poor reading comprehension tend to engage in listing or knowledge telling (Meyer et al., 1980). Good comprehenders are more likely to use the same top-level structure as the text when recalling what was read than poor comprehenders (Meyer et al., 1980). For example, good comprehenders are more likely to use the comparison structure of the biomes passages from the previous example when recalling the passage than poor comprehenders. Furthermore, following the top-level structure of a passage can provide students with “a systematic learning and retrieval guide” (Meyer et al., 1980, p.99). Readers can use the comparison structure of the biomes passage to help them better mentally organize and retrieve information about the biomes being compared. The text structure strategy has been heavily studied (Meyer et al., 2002, 2010; Meyer & Wijekumar, 2014; Wijekumar et al., 2014; Wijekumar, Meyer, & Lei, 2012, 2013, 2017) and found to improve structure strategy competency and reading comprehension. However, the structure strategy has not been thoroughly explored within the science classroom as a way to improve both science literacy and science achievement. The study worked with seventh-grade science teachers on integrating the text structure strategy into daily instruction. The focus on teacher-led text structure strategy instruction over intelligent-tutor led instruction is also a change from recent studies with the text structure strategy and adds to the literature on the text structure strategy as a teacher-led intervention.

Reading skill and science achievement. Another element of the theoretical framework of this study is the potential for reading skill to compensate for low content knowledge. In a study on the impact of science knowledge, reading skill, and reading strategy knowledge, on the science achievement of over 1,600 high school students O’Reilly and McNamara (2007) found that reading skill was significantly correlated to multiple measures of science achievement and that the effect size of reading skill on science achievement measure was moderately large.

O'Reilly and McNamara (2007) measured science knowledge with a researcher-developed 18-item multiple-choice test. Cronbach's alpha for the measure was $\alpha = .74$. Reading skill was measured using the Gates-MacGinitie reading skill test level 7/9. Cronbach's alpha for the Gate-MacGinitie in the study was $\alpha = .95$. Reading strategy knowledge was measured with a 25-item multiple-choice questionnaire. Cronbach's alpha was $\alpha = .72$. Science achievement was measured with 8 multiple choice and 12 open-ended questions over a science passage about meteorology. Cronbach's alpha for the multiple-choice questions was $\alpha = .83$ and $\alpha = .87$ for the open-ended questions. Students' course grade and achievement on the Virginia standardized science tests were also used to measure science achievement.

O'Reilly and McNamara found that reading skill had moderate positive correlations with the multiple-choice questions, $r(1,442)=.527$, and open-ended questions, $r(1,345)= .641$, measures of science achievement and a moderate correlation with a state standardized science text measure of achievement, $r(692)=.582$. These findings support that improvement in reading comprehension can potentially help improve science achievement. Reading was also moderately correlated with science knowledge, $r(1433)=.577$. This finding is relatively unsurprising since reading is the main way students acquire new science knowledge, and it is difficult to acquire knowledge with poor reading comprehension.

O'Reilly and McNamara also ran regressions for each measure of science achievement. Reading skill was a significant predictor for the multiple-choice question ($\beta = .379$), open-ended question ($\beta = .499$), and state science test models ($\beta = .395$). For each of the previously mentioned models, reading skill contributed the most to the model. Again, this shows the positive possibilities of a reading comprehension intervention on improving science achievement on multiple fronts. The effect sizes of reading skill on the multiple-choice question (*d*= .64), open-ended question (*d*= .78), and state science test (*d*= .73) measures were moderately large. The effect size of reading skill on science achievement for students with low science knowledge was moderate to large (multiple-choice question, *d*= .46; open-ended question, *d*= .89; state science test, *d*=.96). O'Reilly and McNamara also found that skilled readers with lower science knowledge scored higher on the science achievement test than students who were less skilled readers yet had higher science knowledge.

This study provides empirical support for the impact of reading skill on science achievement and, more specifically, that reading skill can compensate for lower science knowledge. Further, this study is included in the theoretical framework of the current study because O'Reilly and McNamara show the impact of reading skill on science achievement. O'Reilly and McNamara's findings suggest that skilled readers with low science knowledge may be better able to leverage their reading skills in making inferences that help compensate for a lack of background knowledge, whereas less skilled readers students, despite high science knowledge are less able to harness their science knowledge to compensate for decreased reading comprehension. This study also adds support to the use of the text structure strategy to improve science achievement.

Studies on content area reading have shown success within and outside of content area classrooms. Vaughn, Martinez, and Wanzek (2017) found small to moderate effect sizes for social studies content knowledge acquisition (*ES*=.40) and social studies content-related reading comprehension (*ES*=.20). Vaughn et al.'s study supports the promise of a reading comprehension strategy in a content area class. Additionally, Wijekumar, Meyer, and Lei (2017) found positive outcomes in reading for middle school students. Although Wijekumar et al. (2017)'s intervention took place during the English Language Arts period, the texts used in the intervention were content area texts and the researcher designed measure used science texts. Wijekumar et al. show strategy instruction can have a positive impact on content area reading comprehension as measured by standardized and researcher designed measures. The text structure strategy can help support reading comprehension by providing students with an explicit structure for mentally organizing texts, which in turn, results in improved meaning-making (Meyer & Ray, 2011). Based on the empirical evidence, the text structure strategy seems to be a promising approach in making significant impacts on science literacy and science achievement.

Recent Content Area Literacy Interventions

Science interventions. Seifert and Espin (2012) explored the effects of a text-reading, vocabulary learning, combined (text-reading and vocabulary learning), or control condition on primary outcomes of reading fluency and vocabulary knowledge and a secondary outcome of reading comprehension. The main goal of the study was to identify interventions that had a direct effect on the ease of reading scientific texts by improving fluency and vocabulary for students with learning disabilities. A secondary goal was to improve reading comprehension of scientific texts. Participants in the study were 20 students with documented learning disabilities in grade 10 enrolled in regular education biology classes. Treatment sessions lasted 45 minutes (30 minutes for intervention and 15 minutes for assessment) and the control session lasted 15 minutes (assessment only) and took place over four days with two sessions a week for two weeks. Students in the text-reading condition (designed to improve fluency) and the combined text-reading and vocabulary condition had significantly higher scores on word reading than students in the vocabulary only or the control conditions. Similarly, the vocabulary and combined conditions had significantly higher scores on the vocabulary measure than the text-reading or control conditions. There was no significant difference for reading comprehension.

During the intervention, Seifert and Espin (2012) used passages from a standard biology textbook that was used in four of the five schools that participating students attended, and the study shows promise for using science texts as part of focused interventions aimed at improving science-reading skills for students with learning disabilities. However, the information was not explicitly connected to classroom instruction. Whereas, the text structure intervention used by the current study builds on the use of science passages by utilizing the intervention with passages from current areas of classroom instructional focus in the current science textbook adopted by the school. Seifert and Espin (2012) also found significant results for students with learning disabilities. The text structure intervention extends on Seifert and Espin’s success with students with learning disabilities and teaches the text structure intervention to all students, because current NAEP results show that the majority of students in grades 4, 8, and 12 are struggling with reading comprehension regardless of disability diagnosis (NAEP, 2017). Additionally, Seifert and Espin’s study focused on reading fluency and vocabulary knowledge with a secondary focus of reading comprehension, as a result, Seifert and Espin did not include explicit instruction in reading comprehension strategies or identification of the main idea. In contrast, the main focus of the text structure intervention is improved reading comprehension. This focus is achieved by teaching students to use the structure of a text to scaffold reading comprehension and assist in finding the main idea. Finally, Seifert and Espin's intervention was implemented by two graduate students and Ms. Seifert outside of classroom instruction; classroom teachers were not involved. The text structure intervention, however, is implemented by participating classroom teachers and during classroom instruction in an effort to promote the sustainability of the intervention once the study has ended. Seifert and Espin's study supports investigation into more specific treatments to improve reading comprehension of science texts for students with learning disabilities and as well as students without learning disabilities. This is also supported by the consistently low percentage of students receiving special education services that pass the STAAR grade 8 science test (TEA, 2017). While it is important that students be able to read science texts with ease, if students are not able to comprehend what they read then reading ease is relatively pointless. The text structure strategy fits nicely in this gap because it both provides a specific treatment focused on reading comprehension that can be applied to texts of any topic, including science, and is relatively simple in nature allowing the intervention to be implemented by varying instructors.

Cervetti, Barber, Dorph, Pearson, and Goldshmidt (2012) compared the effects of an integrated approach to science and literacy to separate science and literacy instruction on grade 4 students' science understanding, reading comprehension, science vocabulary, and science writing. The teachers in the study were 94 fourth grade teachers that were randomly assigned to either treatment or comparison conditions. The treatment condition included four investigations that occurred over 10 sessions each, totaling 40 sessions over 22 weeks. Sessions were 45 to 60 minutes in length. Students in the treatment condition significantly outperformed the separate science and literacy condition in science understanding, science vocabulary, and several aspects of science writing.

Teachers in Cervetti et al.'s (2012) intervention were provided with a researcher-developed unit on light. In contrast, the text structure intervention focuses on teaching both teachers and students to use the text structure strategy with any text, thus allowing the intervention to be sustainable when researchers are not present. During the reading and writing activities in Cervetti et al.'s intervention, students were provided with "explicit instruction in the use of targeted inquiry skills and literacy strategies" (p. 639) and were taught to identify keywords in texts and then use them to build the main idea. The text structure intervention is different from Cervetti et al.'s in that the text structure intervention explicitly teaches one reading comprehension strategy that subsumes comprehension skills such as making predictions, summarization, and inferencing. Additionally, the text structure intervention uses the macro-structure (e.g., comparison, cause-and-effect, problem-and-solution) of the passage to guide students in finding keywords (signaling words) to help in constructing the main idea.

Fang and Wei (2010) explored the efficacy of an inquiry-based science curriculum with reading (ISR) in developing students' fundamental and derived science literacies compared to an inquiry-based science (IS) curriculum alone. Participants were 233 grade 6 students nested in two science classrooms. Both the ISR and IS conditions participated in an inquiry-based science curriculum for 50 minutes per day for 22 weeks. The ISR condition also included 15-20 minutes of reading strategy instruction on Thursdays and a home science reading program (HSRP) in which students selected one high-quality science book to take home for the week and share with a family member. Students in the ISR condition significantly outperformed students in the IS condition on all measures.

Fang and Wei's work shows the positive effect that literacy instruction in science can have on overall reading ability and science knowledge. Fang and Wei also point out that they worked closely with the science teachers. The text structure intervention follows this model of working closely *with* science teachers to implement reading strategies to improve student science reading outcomes. However, the strategies used in Fang and Wei's intervention changed week-to-week depending on what the researchers and science teachers felt was the best strategy for the current topic. As a result, it is difficult to determine which strategies had the greatest impact on student progress. The text structure intervention, on the other hand, focuses on a single reading comprehension strategy. Focusing on a single strategy is important to developing and promoting only the strategies that have proven successful in and of themselves.

Combined science and social studies interventions. Boardman, Klingner, Buckley, Annamma, and Lasser (2015) studied the effects of using Collaborative Strategic Reading (CSR) in middle school science and social studies classrooms on students (n=1074) in 19 classrooms in a large urban district during the whole school year. Due to scheduling conflicts, students within the CSR condition were further split into full and partial CSR. Students in the full CSR condition participated in a CSR lesson one day each week in both their science and social studies classes, and students in the partial CSR condition received only one CSR lesson each week in either science or social studies. Small effect sizes were found for both the full and partial CSR conditions on all measures.

Boardman et al. (2015)'s Collaborative Strategic Reading utilizes several strategies throughout the reading process. Because multiple strategies were used, students were also required to remember multiple strategies, and it is difficult to know the individual effects of each strategy. As previously mentioned, the text structure intervention teaches students to use one strategy that subsumes reading comprehension skills such as getting the gist, summarizing, and making inferences. Boardman et al. (2015) taught student to get the gist of the text by identifying the most important who or what in the section and important information associated with the who or what. While this strategy is more explicit than the main idea strategy often given by textbooks, it is still somewhat vague. The text structure intervention provides students with explicit guidance on stating the gist by teaching students to use the structure of the text to find key information and then use a text structure specific stem to write the main idea (i.e., The cause was _____ and the effect was _____). A key feature of CSR is collaborative reading where each student in a group is responsible for a strategy. This takes aspects of reading comprehension out of the reader's hands. In contrast, students are taught to use the text structure strategy on an individual level which mirrors how students will be expected to read and learn most of their lives. While CSR shows promise for improvement of content-area knowledge and reading comprehension, the transfer of skills to content areas needs more attention to improve the learning outcomes.

Teacher Attitudes and Beliefs of Content Literacy

Content-area interventions have shown promise for improving comprehension, vocabulary, and content knowledge (Boardman et al, 2015; Cervetti et al., 2012; Fang & Wei, 2010; Seifert & Espin, 2012). However, content-area instruction does not take place in a vacuum. Teacher beliefs and skills can and do influence the instruction students receive (Kukner & Orr, 2015; Yore, 1991).

In a study of 16 pre-service content areas teachers, Kukner and Orr (2015) found several themes that differentiated pre-service teachers (PSTs) committed to literacy in the content-area and those less certain about the role of literacy in their classroom. These themes are presented in Table 2. Unfortunately, students will face both teachers committed to literacy as well as those less certain about literacy. However, the structure strategy provides benefits to both teacher types. Teachers less certain about literacy in the content-area classroom are provided with clear concrete methods of infusing the strategy into everyday lessons and ways to model and practice the strategy are shown and modeled during professional development sessions. Further, the structure strategy may be more appealing than other strategies to content-area teachers uncertain of using literacy strategies in their classroom. The structure strategy focuses on organizing the content to make the connection between ideas clearer which is likely to seem valuable to teachers less comfortable with literacy practices. The structure strategy also supports teachers committed to using literacy practices in their classrooms. A key theme from these teachers was that they saw the connection between literacy routines and thinking and learning. The structure strategy encourages students to think about the ways ideas are connected in a text and provides students with a means of enhancing learning by using those connections to make better inferences about science ideas and topics.

Table 2

Themes Associated with Preservice Teachers' Views on Literacy

Strong commitment to literacy	Less certain about role of literacy in teaching
Expanded understandings of literacies	Inability to speak fluently about incorporating literacy into teaching
Literacy routines as opportunities for thinking and learning	Lack of metacognitive awareness on how to plan for literacy strategies
Clear connections to curriculum outcomes and relevant authentic assessments	Lack of awareness of need to model literacy strategies

Yore (1991) conducted a survey of secondary science teachers' attitudes and beliefs about reading instruction in science. The Science and Reading Questionnaire was completed by 215 grade 6-12 science teachers in British Columbia. The questionnaire had 25 7-point Likert items with a 12-item attitude subscale and a 13-item belief subscale. On the attitude subscale, respondents generally agreed that science teachers have a responsibility to teach reading in the science content. The majority of respondents agreed that teachers should help students improve reading, be familiar with the theories of the reading process, teach students how to read science materials, and help students move past the literal and toward the interpretive level. However, the majority of teachers did not feel that certification for science should include knowledge of reading instruction. On the belief subscale, respondents generally agreed that reading is more than decoding words on a page. Teachers generally agreed that science background knowledge was needed to move science reading beyond memorization and that students used familiar examples when trying to comprehend new concepts. Similarly, the majority of teachers rejected the idea that a science text required no background knowledge for reading comprehension. A near majority of teachers also agreed that poor readers did not follow the logical structure of paragraphs. This study shows promise for teacher uptake of a reading comprehension intervention in the science content. Science teachers appear to be open to the idea of helping students improve their science literacy and see doing so as a responsibility of the job. Additionally, some teachers also seem to understand the connection between understanding text organization (logical structure of paragraph) and reading comprehension ability.

Science Literacy

Norris and Phillips (2003) argue that reading and writing are "inextricably linked to the very nature and fabric of science, and, by extension, to learning science" (p.226). They also make the case that there are two types of science literacy: fundamental and derived, and that fundamental science literacy is often ignored, which is the thesis of their paper. Fundamental science literacy is defined as being able to read and write in the science content. Derived science literacy is defined as being knowledgeable about science content. In a review of science literacy definitions, Norris and Phillips found that the majority dealt with derived science literacy and that few definitions focused on the ability to read or write in science. Norris and Phillips suggest that a cause for the lack of attention to fundamental science literacy is science teachers' view of reading as a simple process and text as transparent because they are not struggling readers nor is their main focus the study of reading. In further defining fundamental science literacy, Norris and Phillips argue against a view of reading based solely on decoding and finding information. Instead, they favor a view of reading that includes reader background knowledge, decisions on what is relevant in the text, and requires the reader to create meanings and inferences and contextualize information. The text structure strategy supports this view of reading by assisting students as they decide what is relevant in the text and then as they make inferences supported by that information.

CHAPTER III

METHODOLOGY

Design

This quasi-experimental study with pretest and posttest investigated the effects of a text-structure intervention on reading and science achievement of grade 7 students in a rural middle school. The demographics of the school as well as the grade 7 student body are presented in Table 3. The science teachers at the middle school volunteered to implement the text structure intervention during their daily science instruction for 10 weeks starting in November and ending in February. The middle school science classes were organized with three teachers teaching six sections each and one teacher teaching four sections. A team from a large research university in the southwest United States recruited the middle school to participate in the study through a university community relations coordinator. Participating teachers consented to participate and were required to complete two days of professional development related to the study.

Participants

The students. All students enrolled in a grade 7 science class were invited to participate in the study. Parental consent forms were sent home in two waves via the science teachers. In the first wave, 89 students returned consent forms for the pretest. After the second wave, a total of 173 students had returned the signed consent documents to participate in the study for posttest. There were no statistically significant differences between students who submitted consent in wave 1 and wave 2 on demographic variable. Student demographics are presented in Table 4. The STAAR grade 6 reading test scores, see Table 5, indicate that 60% of students with available scores (n=49) at wave 1 reached the approaches level (the minimum level considered passing) and had an average percentile of 47.30. At wave 2, 56% (*n*=86) of students with available scores had reached the approaches level. The reported Lexile based on STAAR grade 6 reading test scores for students at wave 1 and wave 2 ranged from 445L to 1500L. The average Lexile for students at wave 1 was 925L and the average level at wave 2 was 895L. Although there is no direct relationship between Lexile and grade level, 855-1165L represents the range for the middle 50% of readers measured in the middle of grade 6 (Lexile, 2018). Therefore, students before the start of the intervention were reading far below, at, and above grade level. At pretest, 10 were in teacher A's class, 24 were in teacher B's class, 40 were in teacher C's class, and 15 students were in teacher D's class. At posttest, 13 were in teacher A's class, 56 were in teacher B's class, 72 were in teacher C's class, and 28 students were in teacher D's class.

Table 3
Descriptive Statistics of 7th Grade Student Body

	n	%
Total School Enrollment	895	
Grade 7 Enrollment	456	
Female	215	47.15
Race/Ethnicity		
African American	113	24.78
Caucasian	165	36.18
Hispanic	162	35.53
Asian	5	1.1
Two or more races	11	2.41
Economic disadvantage	358	78.29
Special education	41	8.99
Other health impairment	7	1.54
Learning disabilities	18	3.95
Autism	7	1.54
Emotional disturbance	3	0.66
At-risk	274	60.09

Table 4

Demographics of Students with Returned Consents at Wave 1 and Wave 2

	Wave 1		Wave 2	
	n	*%*	*n*	*%*
Female	47	52.81	102	58.96
Race/Ethnicity				
African American	17	19.10	44	25.43
Caucasian	40	44.94	71	41.04
Hispanic	30	33.71	50	28.90
Asian	1	1.12	4	2.31
Two or more races	1	1.12	4	2.31
Economic disadvantage	61	68.54	126	72.83
Limited English Proficiency	11	12.36	16	9.25
Special Education				
Other health impairment	0	0	2	1.16
Learning disability	1	2.25	2	1.16
Autism	1	1.12	2	1.16
Emotional disturbance	1	1.12	1	0.58
At-risk	41	46.07	94	54.34
Teacher				
A	6	6.74	14	8.09
B	32	35.96	54	31.21
C	36	40.54	76	43.93
D	15	16.85	29	16.76

Table 5

Descriptive Statistics of STAAR Grade 6 Reading Results for Students with Returned Consents at Wave 1 and Wave 2

	Wave 1			Wave 2		
	n	*M*	*SD*	*n*	*M*	*SD*
Raw score	79	25.35	8.10	158	24.78	8.04
Percent score	79	62.65	20.27	158	62.11	20.26
Approaches	44			103		
Meets	26			59		
Masters	17			31		
Percentile	79	46.13	29.60	158	44.05	28.52
Lexile	79	909.56	231.99	158	891.15	236.41

The teachers. Teachers completed their consent forms during the first professional development. The four science teachers comprised the entire grade 7 science department.

The teachers agreed to participate in the study by using text structures in their science lessons as appropriate. All teachers were women. One teacher was African American, two teachers were Caucasian, and one teacher did not know her race or ethnic background. Teacher A was new to teaching and was hired in November, prior to the start of the intervention. Prior to her hire, her students had been instructed by a long-term substitute. She held two Bachelor of Science degrees- one in biology and one in cytogenetics. She also held an MBA. Teacher C had 30 years of teaching experience, all teaching science. She held a bachelor’s degree in secondary education with a science composite certificate. Teacher D had four years of teaching experience with three of those years spent teaching science. She held both a bachelor’s degree and a master’s degree in exercise science. Teacher B had five years of teaching experience with four teaching science. She held a bachelor’s degree in interdisciplinary studies with an emphasis in 4-8 math and science.

Measures

Demographic variables. The students’ special education indicator, economic disadvantage status, age, LEP status, gender, race/ethnicity, classroom, and class period were collected.

Standardized tests of reading comprehension. Reading comprehension was measured with the Gray Silent Reading Test (GSRT) (Wiederhold & Blalock, 2000) at pretest and posttest. This test was selected because it can be used in a group setting, has two forms, and tests comprehension processes, including finding the main idea. The GSRT is a multiple choice reading comprehension test comprised of 13 short passages that increase in complexity followed by five multiple-choice questions. This test is designed for readers age seven through 25. Alternate-form reliability was reported in the test manual at 0.85.

Cronbach's α for form A and B were 0.95 and 0.94, respectively. All five major text structures are used in the GSRT in a minimum of one passage. Additionally, the multiple-choice questions necessitate a rephrasing of the information presented in the passage. In this study, Form B was administered at pretest and Form A was administered at posttest. The pretest GSRT score was used as a covariate for data analyses when examining the effects of the text structure intervention on the dependent measures of reading comprehension. The GSRT posttest score was the outcome measure for the second research question.

The STAAR grade 6 reading test was also used as a standardized test of reading comprehension. The measure is administered state-wide and is reported to be valid and reliable. Prior released tests show high reliability (Cronbach's alpha= 0.91). The test includes narrative and expository passages with multiple-choice questions measuring vocabulary and reading comprehension for each grade level. The STAAR grade 6 test was also used as a covariate for data analysis when examining the effects of the text structure intervention on the dependent measures of reading comprehension.

Standardized test of science knowledge. To measure students' current science knowledge, a researcher created science knowledge assessment (SKA) using released STAAR grade 8 science test questions was administered at pretest and posttest. Using the Texas Essential Knowledge and Skills (TEKS) as a guide, all released STAAR grade 8 science tests were reviewed for questions that were listed by the Texas Education Association (TEA) as addressing grade 7 and 6 TEKS. Only questions addressing grades 6 and 7 TEKS were used because students could reasonably be expected to have learned information tested in questions covering grade 6 TEKS the previous year and to learn information tested in questions covering grade 7 TEKS during the course of the current school year. Students could not reasonably be expected to know the material in questions covering grade 8 TEKS. Questions from the released tests that assessed grade 6 and 7 TEKS were then compiled. The resulting list of test questions was then divided into two sets of test questions. With exception of TEKS 7.6(B) and 7.11(A) which were only tested once across all released tests, all TEKS were tested a minimum of two times. Table A-2 in the Appendix lists the TEKS assessed in the modified test. Validity and reliability of the STAAR tests were established by an independent company contracted by TEA. The reported Cronbach's alpha reliability of the STAAR grade 8 science test is 0.91 and an expert review panel agreed that test items were 97.7% aligned with expectations.

Experimenter-designed measures of reading comprehension. Student use of problem and solution and comparison text structures was tested using two equivalent test forms. One form was administered before teachers began using the text structure intervention in their classrooms and the second form was administered immediately after the conclusion of the intervention. Each form had two passages: one passage using the problem and solution text structure and one passage using the comparison text structure. Identification of the top-level structure and competence were assessed with both the problem and solution and comparison passages. Signaling word identification was measured using the comparison passage. Additionally, the comparison passage had the additional variable of number of issues compared.

Problem and solution text structure passage. The two problem and solution passages dealt with a) rats and b) dogs. The passages were equivalent; each having 98 words, 72 idea units, and equivalent scores on readability, text structure, and signaling (Meyer, 2003). Each problem and solution passage presented students with a problem that was relatively unfamiliar, the cause of the problem, and a solution that eliminated the cause of the problem. Students were asked to read the passage, remove the passage from their sight by putting it in an envelope, and then write all that they could recall about the problem and solution passage. The dependent variables for the problem and solution passage are top-level structure and competency in using the problem and solution text structure to organize the recall.

Comparison passage. The topic of the comparison passage on the pretest or posttest was either a) Hagar Qim Stone Circles compared to Stonehenge or b) Mt. Rushmore compared to Easter Island. Students were asked to complete three tasks using the comparison passage: 1) a fill in the blank cloze task with 5 blanks testing knowledge of comparison signaling words, 2) a main idea task where students were asked to write a main idea no longer than two sentences with the passage in view, and 3) a recall task with the passage out of view, similar to the problem and solution recall task. Dependent variables for the comparison passage included top-level structure, comparison competency, number of issues compared, and signaling word test scores.

Text structure strategy use in classrooms. Use of the text structure strategy was recorded during each classroom visit. During each visit, if the text structure strategy was appropriate for the lesson, if the teacher used the text structure strategy during the lesson, if I used the text structure strategy during the lesson via co-teaching, and if I modeled the lesson (i.e., I taught the whole lesson).

Scoring

GSRT. The GSRT was scored using the scoring procedures stated in the testing manual.

Science knowledge assessment. The SKA was scored using the answers provided by TEA for each released STAAR grade 8 science test.

Experimenter-designed measure of reading comprehension. The signaling word responses for the comparison passage were scored using computer algorithms. Correct answers for each blank were given a score of 7 with a maximum possible score of 35.

The top-level structure, competence, quality, and number of issues compared measures were scored by a trained member of the research team. Problem and solution and comparison competence from the main idea and two recall tasks were scored using manuals from previous text structure intervention studies (Meyer et al., 2010; Wijekumar et al., 2014). The recalls were scored on an 8-point scale and the main idea was scored on a 6-point scale. Both recalls (problem and solution, comparison) and the main idea (comparison) assessed students' proficiencies in using the text structures as taught during the text structure intervention. Table 6 shows examples of the scoring points and criteria for the researcher designed measure.

Table 6

Researcher Designed Outcome Measures and Scoring Approaches with Examples

Construct measured	Scoring approach and examples of scoring guidelines
Problem and Solution Source:	
Problem and Solution competency and Full Recall (without passage in view)	
Problem and Solution Competency	Score 1-8 1 = no problem, no solution, and no cause 2 = signaled cause but no problem and no solution 3 = one part of the problem and solution 4 = problem and cause but no solution or incorrect solution 5 = problem and solution (correct content of problem) and correct content of solution 6 = problem, solution & cause of the problem mention only in the solution part. 7 = similar to 5 but additionally presented the cause of the problem when discussing the problem 8 = problem, solution, and cause in the problem and cause eliminated in the solution part
Problem and Solution Full Recall	Total number of ideas recalled
Comparison Text Structure Source:	
(1) Signaling word scores based on fill in the blanks- Cloze Task, (2) Main idea score- Write a main idea for the passage (with passage in view) (3) Comparison competence and full recall score- Write a recall (*without* passage in view)	
Signaling Word Score (Cloze Task) 7 points max for each of fill-in-the-blank words	Score 1-7 1 = any word 2 = words that show understanding of two animals being compared but not signaling words (e.g., "joining") 3 = signaling words, but not for the comparison structure (e.g., "solution") 4 = comparison signaling words with different intent (e.g., "smaller than" when larger than fit the context) 5 = similar signaling word (e.g., "also like") 6 = misspelled or parts of signaling words (e.g., "same") 7 = exact signaling words (e.g., "same as")
Comparison Main Idea Quality	Score 1–6 1 = no mention of two ideas compared and no mention of what attributes they were compared on 5 = correct identification of the entities compared and at least one attribute on which they were contrasted. 6 = criteria for 5 (above) but with at least 2 attributes/issues and one of the issues was a super-ordinate issue constructed from the text

Adapted from Wijekumar, Meyer, Lei (2013)

Procedures

Implementation continuum of text structure intervention. The text structure intervention is implemented through a continuum of activities grouped into five phases, see

Figure 1, starting with professional development and moving toward student independence. This means that intervention activities move toward student independence but can also move back toward professional development depending on the needs of both teachers and students. The first phase of the continuum is professional development where teachers learn about the intervention and practice using the intervention with upcoming lessons. The second phase is planning for text structure. In this phase, teachers purposefully plan for the use of the text structure strategy in upcoming lesson plans. This includes identifying the text structure of texts to be read, finding signaling words within the texts, writing the main idea using the text structure specific stem, as well as considering the organization of topics being covered (e.g., comparison, cause-and-effect, problem-and-solution). Once teachers have planned for the use of the text structure in their lessons, they move to the teacher modeling phase. In this phase, teachers explicitly model using the text structure strategy during classroom instruction. Teachers model the strategy for students until they feel that students are ready to move to the next phase: student practice with teacher guidance. In this phase, students practice using the text structure strategy as teachers provide support either in a whole class, group, or individual setting. This means that teachers provide support and guidance in using the text structure strategy as students are working (e.g., pointing out signaling words, checking use of correct main idea stem, etc.). During this phase, teachers are also checking to see student proficiency in using the strategy. Depending on student proficiency, teachers may go back to the modeling phase or move to the student independence phase. If students are showing proficiency, teachers can move to the student independence phase where students use the text structure strategy without assistance. Throughout the intervention time frame, teachers continually return to the planning for text structure phrase as they plan for upcoming lessons. Additionally, teachers can request more professional development via modeling, coaching, and/or assistance with planning at any point during the intervention.

Text Structure Strategy Intervention				
Professional development	Planning for text structure instruction	Teacher modeling	Student practice with teacher guidance	Student independence

Figure 1 *Implementation Continuum of Text Structure Strategy Intervention*

Implementation activities. To implement the text structure strategy in middle-school science classrooms, nine activities that moved both teachers and students through the phases of the implementation continuum were planned for use in and out of the classroom. Once the intervention was in progress, modifications were made to provide the greatest amount of support for teachers. Table A-3 in the Appendix presents the timeline and activities related to the intervention delivery and data collection.

Planned Activities and Modified Activities

1. **Pre-intervention professional development** *(Professional development phase)*

   Planned activity: Two days of practice-based professional development.

   - Day one: Teachers learn the research behind the text structure strategy.
   - Day two: Teachers participate in multiple opportunities to practice implementing the strategy in their classrooms.
     - Review upcoming lessons and identify text structure of supporting texts (e.g., Comparing body systems)

- Identify structure-specific signaling words within texts (e.g., similar, contrast)
- Create of graphic organizers using text structure
- Write main ideas of texts using the structure-specific stems (e.g., _____ and _____ were compared on _____, _____, and _____.)
- Create inference questions for texts (e.g., Why is heart health important to the circulatory system?)
- Create elaboration activities for lesson topic (e.g., Research health issues that can affect the nervous system)

- Addition professional development available as needed and requested (i.e., modeling lessons).

Modified activity: No modifications were made during implementation

2. **Weekly - Pre-Instruction Activities (50 Minutes/Week)** *(Planning for text structure phrase)*

Planned activity: Two planning sessions per week (50 minutes/session)

- Analyze upcoming texts in terms of text structure with researcher support
  - Identify text structure of texts
  - Identify signaling words in texts
  - Create graphic organizers using text structure
  - Write main ideas of texts using the structure-specific stems
  - Create inference questions for texts
  - Create elaboration activities for lesson topic
  - Researcher models how to present information to students

- Teachers model presentation of information to their students.

Modified Activity: One planning session per week

- Teachers focus on TEKS
- Research suggested text-structure organization for covered material (e.g., animal adaptations as cause and effect)
- Researcher created semi-structured lesson plans (Figure A-1 in Appendix)
    - Found texts connected to current topics
    - Adapted texts to be more clearly signaled
    - Created graphic organizers using text structure
    - Provided main idea written using text structure specific stem
    - Created inference questions for text

3. **Classroom-implementation** *(Teacher modeling, student practice with teacher guidance, student independent practice phases)*

a. ***Identifying text structure in science texts***

Planned activity: In-class instruction about the signaling words

- Teacher identification of text structure of text being read
    - Teacher models identification of signaling words (e.g., similar, because, result)
    - Teacher models classification of text structure based on the signaling words (e.g., similar, different, alike, contrast = comparison text structure)
    - Teacher gradually releases students to independence

Modified activities: In-class instruction about signaling words

- Limited practice prevented teacher release to independence

b. ***Reading using the text structure strategy with science texts***

<u>*Planned activity:*</u> In-class instruction on using text structure to support reading comprehension

- Teacher explicit instruction using text structure to support reading comprehension
  - Think-alouds and text annotation focused on comparisons, causes-and-effects, and problems-and-solutions (e.g., "I see the word because and I know that means the cause of an event is going to be stated after that word", circling signaling words and writing the text structure that goes with the word)
  - Teacher gradually releases students to independence

<u>*Modified activity:*</u> In-class instruction using semi-scripted lesson plan

- No modifications needed if teacher followed semi-scripted plan

c. ***Selecting important ideas from the text***

<u>*Planned activity:*</u> In-class instruction on getting the gist of the text

- Instruction on using the main idea pattern to find the important ideas – comparison (e.g., _____ and ___ were compared on ____, ____, and ____) (i.e., Cells, tissues, organs, and organ systems were compared on structure, function, number of cells, and complexity)

<u>*Modified activity:*</u> In-class instruction on getting the gist using semi-scripted lesson plan

- No modifications needed when teacher followed semi-scripted plan

d. ***Connecting the ideas using the text structures to generate hierarchical and logical memory structures***

Planned activity: In-class instruction on generating a memory tree to check mental organization of information

Modified activity: Due to limited instructional time this activity was often left out of lessons.

e. ***Generating inferences based on the diagrams and text using text structures***

Planned activity: In-class instruction on using text and previous experiences and/or additional information in the text to generate inferences, no modifications were needed when teacher followed semi-scripted lesson plan

f. ***Elaborating and background knowledge extension***

Planned activity: Investigation and research extending background knowledge and motivation toward current topic

Modified activity: Due to limited instructional time no elaboration or background knowledge extension activities were performed.

g. ***Monitoring reading comprehension self-check***

Planned Activity: In-class support of students understanding using the text structure strategy, no modifications were needed when teacher followed semi-scripted lesson plan

Testing. Students were randomly assigned to take either Form A or B of the GSRT. The testing was conducted during science classes and was administered by me. The SKA was administered by the school to all grade science students. All students at the middle school received the text structure strategy intervention. After 10 weeks of the text structure strategy intervention, students were given an immediate posttest. The posttest had the same condition as the pretest.

Scoring. The prose analysis system of Meyer (1975, 1985) programmed into a computerized scoring system was be used to score the experimenter designed measures. This approach is efficient and provides consistent high reliability to the scores.

Research Questions

1. Were there pre-posttest improvements in science and reading comprehension scores for seventh-grade students using the text structure strategy for 10 weeks?
2. Were there differences in improvements based on gender, ethnicity, economic status, language proficiency?
3. Were there any teacher effects on student learning outcomes?
4. Do students with lower pretest science scores (i.e., raw score below 12, 41%) demonstrate better improvements after intervention than those with higher pretest scores?

Method

To answer RQ1, a series of paired *t*-tests were conducted comparing all posttest and pretest scores. If posttest scores were significantly higher than the pretests scores, we would conclude that the intervention was effective.

To answer RQ2 and RQ3, ANOVA analyses were conducted on all posttest scores. We were investigating if gender, ethnicity, economic status, language proficiency affected posttest scores, after controlling for pretest scores. Teacher effect was examined on science tests only.

To answer RQ4, ANOVA analyses were conducted on science knowledge assessment gain scores (i.e., posttest-pretest scores). We first dummy coded the science pretest capacity based on pretest raw scores. If students scored below 12 on science knowledge pretest in raw score format, they would be coded as “poor science knowledge”; otherwise they would be coded as “good science knowledge”. Therefore, the focal independent variable is the science pretest capacity, but meanwhile we are controlling all demographic variables. SAS version 9.4 was used for all analyses. Missing data was deleted listwise.

CHAPTER IV

RESULTS

Research Questions

The primary research question was whether there were pretest to posttest improvements in science and reading comprehension scores for grade 7 students using the text structure strategy for 10 weeks. Secondary research questions were (1) whether there were differences in improvements based on gender, ethnicity, economic status, language proficiency (2) whether there were any teacher effects on student learning, and (3) whether students with lower pretest science knowledge scores (i.e., raw score < 12) demonstrated better improvements after intervention than those with higher pretest scores.

Descriptive Statistics

Table 7 summarizes pretest and posttest means and standard deviations for signaling word knowledge, GSRT Age-equivalent score, GSRT Grade-equivalent score, SKA raw score, main idea competency, and main idea quality. Signaling word mean at pretest was 9.32 (*SD* = 4.70) and was 11.38 (*SD* = 5.74) at posttest. GSRT age-equivalent score mean at pretest was 11.35 (*SD* = 2.72) and was 11.56 (*SD* = 2.82) at posttest. GSRT grade-equivalent score mean at pretest was 5.60 (*SD* = 2.70) and was 5.81 (*SD* = 2.81) at posttest. SKA raw score mean at pretest was 14.38 (*SD* = 4.52) and was 17.35 (*SD* = 2.81) at posttest. Main idea competency mean at pretest was 1.21 (*SD* = 0.45) and was 1.20 (*SD* = 0.62) at posttest. Main idea quality mean at pretest was 1.19 (*SD* = 0.43) and was 1.29 (*SD* = 0.51) at posttest.

Except for the main idea competency, other posttest scores are all higher than the corresponding pretest scores. In addition, there are 126 economically disadvantaged students (cf, 47 non-disadvantage), 16 students with limited English proficiency (cf. 141 non-LEP), 71 Caucasian (cf. 44 African American, 50 Hispanic, 4 Asian and 4 more than one race), 71 males (cf. 102 females). Moreover, these students are instructed by four different science teachers (teacher A, *N*=14; teacher B, *N*=54; teacher C, *N*=76; teacher D, *N*= 29)

Table 7
Descriptive Statistics of Pretest and Posttest Scores

	Pretest			**Posttest**		
	N	*Mean*	*SD*	*N*	*Mean*	*SD*
Signaling word	72	9.32	4.70	160	11.38	5.74
GSRT Age-equivalent score	88	11.35	2.72	170	11.56	2.82
GSRT Grade-equivalent score	88	5.60	2.70	170	5.81	2.81
SKA raw score	146	14.38	4.52	168	17.35	7.42
Main Idea Competency	62	1.21	0.45	155	1.20	0.62
Main Idea Quality	63	1.19	0.43	155	1.29	0.51

Note. GSRT = Gray Silent Reading Test; SKA= Science Knowledge Assessment

Text Structure Intervention Effectiveness (Primary Research Question)

Paired *t*-tests were conducted to compare signaling word knowledge, GSRT age-equivalent score, GSRT grade-equivalent score, SKA raw score, main idea competency, and main idea quality at pretest and posttest. Results showed that all scores, except main idea competency, significantly improved after the intervention (see Table 8). There was a significant improvement in signaling word knowledge from pretest (*M*= 9.32, *SD*= 1.14) to posttest (*M*= 11.38, *SD*= 5.74); $t(65) = 5.20$, $p < .0001$. There was a significant improvement on GSRT age-equivalent score from pretest (*M*= 11.35, *SD*= 2.72) to posttest (*M*= 11.56, *SD*= 2.82); $t(85) = 4.30$, $p < .0001$. There was a significant improvement on GSRT grade-equivalent score from pretest (*M*= 5.60, *SD*= 2.70) to posttest (*M*= 5.81, *SD*= 2.81); $t(85)$ =

4.29, *p* < .0001. There was a significant improvement on SKA raw score from pretest (*M*= 14.38, *SD*= 4.52) to posttest (*M*= 17.35, *SD*= 7.42), *t*(141) = 5.97, *p* < .0001. There was a significant improvement on main idea quality from pretest (*M*= 1.19, *SD*= 0.43) to posttest (*M*= 1.29, *SD*= 51), *t*(60) = 2.19, *p* = .038. There was no significant improvement on main idea competency from pretest to posttest.

Table 8

Paired t-Tests Comparing Pretest vs. Posttest Scores

	Mean diff	**95% CL Mean diff**		**DF**	**t Value**	**Pr > |t|**	**BH adjusted p values**
Signaling word	3.21	1.98	4.45	65	5.20	<.0001***	<.0001***
GSRT Age-equivalent score	0.97	0.52	1.42	85	4.30	<.0001***	<.0001***
GSRT Grade-equivalent score	0.97	0.52	1.42	85	4.29	<.0001***	<.0001***
SKA raw score	3.11	2.08	4.14	141	5.97	<.0001***	<.0001***
Main Idea Competency	0.03	-0.18	0.25	59	0.31	0.76	0.76
Main Idea Quality	0.20	0.02	0.38	60	2.19	0.0327*	0.038*

Note. GSRT = Gray Silent Reading Test; SKA= Science Knowledge Test

Effect of Gender, Ethnicity, Economic Status, Language Proficiency, and Teacher on Intervention Effectiveness (Research Questions 2 and 3)

ANOVA analyses were conducted on all posttest scores. ANOVA analyses are displayed from Tables 9 to 14. After controlling for pretest scores and other demographic variables, males outperformed females on science knowledge posttests in the raw score form (*p*=.015; see Table 12). The *p* value adjusted by the Benjamini Hochberg (BH) method was also significant (*p* adjusted= .046). After controlling for pretest and other demographic variables, economic status significantly affected main idea quality posttest scores (*p*= .025). However, the BH-adjusted *p* value was .127, suggesting the significance may be caused by the multiple testing error. None of the posttests were affected by English proficiency or ethnicity. Also, the science posttest scores were not affected by teacher differences. To conclude, only gender was a significant demographic predictor, but it only affected SKA scores in the raw score format.

Demographic effects on signaling word posttest. Signaling word pretest had a significant effect on posttest; F= 23.77, p < .0001 (see Table 9). No other variables had a significant effect. This means that students who performed well on the signaling word pretest also performed well on the posttest.

Table 9

Demographic Variable Effects on Signaling Word Posttests

	DF	Type III SS	Mean Square	F Value	Pr > F
Signal word pretest	1	613.60	613.60	23.77	<.0001
Gender	1	2.87	2.87	0.11	0.74
Ethnicity	3	29.76	9.92	0.38	0.7647
LEP	1	2.33	2.33	0.09	0.7648
Economic status	1	32.03	32.03	1.24	0.2703
Error	53	1367.89	25.81		

Demographic effects on GSRT age-equivalent posttest. GSRT age-equivalent pretest had a significant effect on posttest; F= 86.92, p < .0001 (see Table 10). No other variables had a significant effect. This means that students with a higher GSRT age-equivalent at pretest had a higher GSRT age-equivalent at posttest.

Table 10

Demographic Variable Effects on GSRT Age-equivalent Posttests

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GSRT age-equivalent pretest	1	386.86	386.86	86.92	<.0001
Gender	1	0.05	0.05	0.01	0.9152
Ethnicity	3	3.37	1.12	0.25	0.8595
LEP	1	0.001	0.001	0.001	0.9865
Economic status	1	9.16	9.16	2.06	0.1558
Error	72	320.45	4.45		

Note. GSRT = Gray Silent Reading Test

Demographic effects on GSRT grade-equivalent posttest. GSRT grade-equivalent pretest had a significant effect on posttest; $F = 85.07$, $p < .0001$ (see Table 11). No other variables had a significant effect. This means that students with a higher GSRT grade-equivalent at pretest had a higher GSRT grade-equivalent at posttest.

Table 11

Demographic Variable Effects on the GSRT Grade-equivalent Posttest

Source	DF	Type III SS	Mean Square	F Value	Pr > F
GSRT grade equivalent pretest	1	378.035	378.035	85.07	<.0001
Gender	1	0.09503	0.09503	0.02	0.8841
Ethnicity	3	3.33625	1.11208	0.25	0.8609
LEP	1	0.001	0.001	0.001	0.9868
Economic status	1	8.82042	8.82042	1.98	0.1632
Error	72	319.96	4.44		

Note. GSRT = Gray Silent Reading Test

Demographic and teacher effects on SKA raw score posttest. SKA raw score pretest had a significant effect on posttest; *F*= 58.24, *p* < .0001 (see Table 12). Gender also had a significant effect on SKA raw score posttest; *F*= 6.06, *p* = .015. No other variables had a significant effect. This means that students with a higher SKA raw score at pretest had a higher SKAW raw score at posttest. This also means that male students performed higher than female students.

Table 12

Demographic Variable Effects on the SKA Posttest Raw Score

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SKA pretest raw score	1	2315.42	2315.42	58.24	<.0001
Gender	1	240.77	240.77	6.06	0.0153*
Ethnicity	4	118.32	29.58	0.74	0.5639
LEP	1	27.52	27.52	0.69	0.4071
Economic status	1	0.001	0.001	0.001	0.9945
Teacher	3	79.51	26.50	0.67	0.5742
Error	119	4731.29	39.76		

Note. SKA= Science Knowledge Test

Demographic effects on main idea competency posttest. Main idea competency pretest did not have a significant impact on posttest, neither did any demographic variables. (see Table 13).

Table 13

Demographic Variable Effects on Main Idea Competency Posttest Scores

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Main idea competency pretest scores	1	0.20	0.20	0.45	0.5058
Gender	1	0.85	0.85	1.9	0.1741
Ethnicity	3	0.34	0.11	0.26	0.8563
LEP	1	0.16	0.16	0.36	0.5496
Economic status	1	0.24	0.24	0.54	0.4664
Error	47	20.88	.44		

Demographic effects on main idea quality posttest. Economic status had a significant effect on main idea quality at posttest; $F = 5.32$, $p = .025$ (see Table 14). No other variables had a significant effect. This means that students with from a higher economic background performed higher at posttest.

Table 14

Demographic Variable Effects on Main Idea Quality Posttest Scores

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Main idea quality pretest scores	1	0.074	0.074	0.23	0.631
Gender	1	0.64	0.641	2.02	0.162
Ethnicity	3	0.05	0.017	0.05	0.984
LEP	1	0.14	0.14	0.44	0.508
Economic status	1	1.69	1.69	5.32	0.025*
Error	48	15.23	0.32		

Effect of Science Knowledge Pretest on Learning Outcomes (Research Question 4)

Our analyses on science gain scores suggest that the gains in science knowledge from pretest to posttests were not significantly affected by pretest levels (i.e., those who scored below vs. above 12 on SKA pretest raw scores; see Table 15).

Table 15

Effect of Science Pretest Capacity on Gain Scores (Science Knowledge Raw Scores)

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Science pretest ability	1	0.83	0.83	0.02	0.8850
Gender	1	240.74	240.74	6.06	0.0153
Ethnicity	4	120.21	30.05	0.76	0.5560
LEP	1	26.48	26.48	0.67	0.4161
Economic status	1	0.03	0.03	0.03	0.9771
Teacher	3	77.23	25.74	0.65	0.5860
Error	119	4730.88	39.76		

Text Structure Strategy Use During Classroom Observations

Table 16 presents the number of observed lessons, the percentage of lessons where text structure was appropriate, the percentage of lessons where the teacher used text structure, the percentage of lessons I co-taught (i.e., I provided impromptu text structure instruction in support of the planned lesson), and the percentage of lessons that I modeled (i.e., I taught the planned lesson). Teacher A was observed 19 times. Eighty-four percent of Teacher A's observed lessons were appropriate for using the text structure strategy. Teacher

A used the text structure strategy in 32% of observed lessons and I used the text structure strategy via co-teaching in 32% of Teacher A's observed lessons. I modeled text structure instruction during 37% of Teacher A's observed lessons. Teacher B was observed 16 times. Ninety-four percent of Teacher B's observed lessons were appropriate for using the text structure strategy. Teacher B used the text structure strategy in 13% of observed lessons and I co-taught during 88% of lessons. I modeled no lessons for Teacher B. Teacher C was observed 20 times. Ninety-percent of Teacher C's observed lessons were appropriate for using the text structure strategy. Teacher C used the text structure strategy in 20% of observed lessons and I co-taught 45% of Teacher C's observed lessons. I modeled the lesson for 30% of Teacher C's observed lessons. Teacher D was observed 16 times. One-hundred percent of Teacher D's observed lessons were appropriate for using the text structure strategy. Teacher D used the text structure strategy in 81% of observed lessons and I co-taught 50% of Teacher D's lessons. I modeled the lesson for 44% of Teacher D's observed lessons.

Table 16
Text Structure Strategy Use During Classroom Observations

Teacher	Lessons observed	% of lessons where text structure was appropriate	% of lessons that teacher used text structure	% of lessons co-taught by researcher	% of lessons modeled by researcher
A	19	84.21	31.58	31.58	36.84
B	16	93.75	12.50	87.50	0.00
C	20	90.00	20.00	45.00	30.00
D	16	100	81.25	50.00	43.75
Total	71	91.55	35.21	80	28.17

CHAPTER V

CONCLUSIONS

This study investigated the efficacy of the text structure strategy intervention as a means of improving science knowledge and science reading comprehension in grade 7 science classes. The text structure strategy is a reading comprehension strategy designed to teach students how to use the macro-structure of a text to improve reading comprehension of science texts by selecting key ideas, stating the gist of the text (e.g., the main idea), summarizing, making inferences, elaborating, and monitoring their reading comprehension. The results showed that signaling word knowledge, GSRT Age equivalent score, GSRT Grade equivalent score, the SKA raw score, and main idea quality all significantly increased from pretest to posttest. Additionally, the results also showed that gender had a significant effect on SKA posttest and economic status had a significant impact on main idea quality at posttest.

Research Finding in Context

The text structure strategy is only truly useful to students if they are able to transfer their knowledge of the strategy to various assessments and use that knowledge to improve reading comprehension. The GSRT is a standardized measure of reading comprehension that uses each text structure (cause-and-effect, problem-and-solution, etc.) a minimum of one time. As a result, the GSRT is an appropriate distal measure of text structure knowledge. The SKA can also be considered a distal measure because students must transfer their text structure knowledge to help them comprehend and then answer science knowledge questions. The main idea writing task is a proximal task as is the signaling word task. However, the signaling word task is slightly more distal because students were taught to identify signaling words during classroom instruction but completed a signaling word cloze task on the research developed measure.

Text Structure Intervention Effectiveness (Primary Research Question)

The primary research question of this study was whether the text structure intervention in the science classroom effectively improved signaling word, reading comprehension, students' science knowledge and main idea capacities. Paired *t*-tests showed significant improvements from pretest to posttest for the GSRT, SKA, main idea quality, and signaling word suggesting that students' capacities in these areas improved.

In contrast, Seifert and Espin (2012) tested reading comprehension using 10 multiple choice researcher developed questions given after each intervention session and did not find significant differences for reading comprehension. This comparison is important because in this study the GSRT, SKA, main idea quality, and signaling word measures were used as measures of reading comprehension. The GSRT is a standardized measure of reading comprehension. The SKA, main idea quality, and signaling words can also be considered measures of reading comprehension because reading comprehension is required to answer the science knowledge questions, write a strong main idea, and determine the best word to complete the blank. Seifert and Espin's intervention focused on reading fluency and vocabulary, and they did not find effects on reading comprehension. However, this study provided focused reading comprehension strategy instruction and found significant differences on several measures. This difference is important because reading comprehension in the content areas cannot be hoped for as a secondary result of instruction on prerequisite skills such as fluency and vocabulary. The specific aim must be reading comprehension strategies.

The significant increase in main idea quality and signaling word knowledge provides support for the use of the text structure strategy in a science classroom. Being able to state the main idea is an important indicator of the ability to select important ideas while reading and also take advantage of the logical connections placed in the text by the author. Additionally, being able to correctly add signaling words to a text is an important indicator of the ability to understand how authors connect ideas within texts.

These findings are especially significant given the modifications to teacher planning for text structure and in-class instruction that were made and resulted in reduced dosage of the intervention. Prior to implementation, it was planned for teachers to plan for and practice use of the text structure strategy during the PLC time. Additionally, it was assumed that students would be regularly reading during the science class period and have frequent opportunities to use the strategy. However, the structure of the PLC time and limited text resources resulted in limited teacher planning for the text structure strategy and limited in-class instruction of the text structure strategy. As a result, I created six semi-scripted text structure strategy lesson plans using upcoming science content for the teachers to counteract the reduced planning time. The semi-scripted lessons were the students' main instruction in the text structure strategy.

Additionally, I modeled lessons for teachers A, C, and D. Teacher B's instructional schedule did not allow for modeling (see Table 16 for percentages). In addition to modeling, I also co-taught with the teachers. When co-teaching, I pointed out how text structure was useful to the current instructional activity (e.g., Test review questions used cause and effect signaling words that could help students better understand what the question was asking) and encouraged students to use the text structure strategy.

Although I modeled, co-taught, and added general text structure support to lessons, I observed that, except for Teacher D, the teachers were not taking full ownership of the intervention. This can be seen in the low percentage (13-32%) of Teachers A, B, and C's use of the text structure strategy during observations compared with the percentage of lessons where the text structure strategy was appropriate (84-100%). The low percentage of Teacher A and C using the text structure strategy in during observed lessons compared with the percentage of modeled lessons also indicates that the teachers did not full ownership of the intervention in their classrooms. Teachers saw the text structure fully modeled and used the semi-scripted lessons but did not actively use the text structure strategy with other materials. The improvements in main idea quality and signaling words suggest that even in limited doses instruction in the text structure strategy is powerful.

Effect of Gender, Ethnicity, Economic Status, Language Proficiency, and Teacher on Intervention Effectiveness (Research Questions 2 and 3)

Additionally, this study showed that economic status had a significant impact on main idea quality. Previous studies of science interventions and science achievement (Fang & Wei, 2010; O' Reilly & McNamra, 2007) have included students from various economic backgrounds in their studies but did not report results based on economic status. This finding goes beyond previous studies and presents an area for future investigation. It is important to understand why and how students from economically disadvantaged backgrounds are struggling. Future research may focus on the vocabulary knowledge and possible reading challenges of students from economically disadvantaged background. All of the students with limited English proficiency in this study were also from economically disadvantaged backgrounds. Therefore, future research may also focus on students with limited English proficiency.

This study found no significant differences on student performance at the teacher level. A multi-level model analysis with students nested in classrooms was run and no effects were found. This finding is important because teachers A, B, C, and D varied greatly in classroom management, instructional style, and student make up. The researcher as co-teacher model has been employed by other studies and found to be effective (Boardman et al., 2015; Feng & Wei, 2010). However, this type of researcher-co-teacher model works well for small scale studies but is not sustainable in larger studies. Future studies need to explore how instructional ownership can be effectively transferred to the teacher so that they are able to independently deliver the intervention.

The significant difference from pretest to posttest on the SKA is similar to other findings about reading based science interventions (Cervetti et al., 2012; Fang & Wei, 2010; Vaughn et al, 2009; Vaughn et al, 2017). However, due to the lack of a comparison group, this study is unable to determine how much of this growth can be attributed to instruction in the text structure strategy. The finding of significant gender effects on science knowledge is consistent with other research on science achievement (Mau & Lynn, 2000; O'Reilly & McNamara, 2007; Reis & Park, 2001) as well as national and state-wide results of science achievement (NAEP, 2015; TEA, 2018). These differences may be a result of different subject area interests. Cunningham, Hoyer, and Sparks (2015) report a significant difference in male and female students' interest in science. Cunningham at al. (2015) also report a significant difference for interest in science by gender and race/ethnicity. However, the difference may be a result of the question content. Based on the High School Transcript

Study, a significantly higher number of female students earned credits in advanced biology (e.g., AP/IB biology, physiology, anatomy, and genetics) and chemistry, while a significantly higher number of males earned credits in physics (Cunningham, 2015). The differences in performance may then also be a result of content area knowledge and test question content. Future research with the text structure strategy in science should investigate why and how male and female students differ on the SKA. Based on previous research, areas of focus may include questions about interest in science, future educational and/or career plans, and analysis of test question content.

Effect of Science Knowledge Pretest on Learning Outcomes (Research Question 4)

This study found that student gains in science knowledge from pretest to posttest were not significantly affected by science pretest level. This finding is significant because it supports the text structure strategy as an equally effective intervention for all students. The majority of students with learning disabilities spend 80% of their time in the general education classroom, most frequently science and social studies classes (Aud et al., 2010). A reading comprehension intervention that helps both high and low achieving students is then perfectly suited for the science classroom where students of all abilities are expected to learn.

Limitations of the study

This study has several limitations. This study explores the relationships among many important factors associated with middle-grade science reading comprehension. Thus, it is not fully powered to draw definitive causal conclusions but to serve as a starting point for a longer research agenda. The results of this study do not generalize to a larger population of learners. We present demographic information so that the readers may understand the context for the study and research outcomes. Additionally, the study is a short duration of 10 weeks and further investigations will be necessary to study longer-term impacts of the intervention. Further, this research uses a quasi-experimental pretest-posttest design without a comparison group limiting the ability to draw causal conclusions from the study. Future studies will include a comparison group and use matching techniques to compare the results of the intervention classrooms with the comparison group classrooms on pretests and posttests.

Significance of the Study

This study contributes to the limited body of knowledge about interventions to improve science text reading comprehension within the middle-grade science classroom. Many reading intervention studies focus on reading comprehension through expository and content area texts but do so through the ELA classroom (Denton et al., 2017; Simmons et al., 2014; Solis, Vaughn, & Scammacca, 2015; Vaughn et al., 2012; Vaughn et al., 2015; Vaughn, Solis, Miciak, Taylor, & Fletcher, 2016; Wanzek et al., 2017). This study also adds to the literature on the relationship between reading comprehension, as measured by a standardized measure, main idea writing, and signaling word knowledge, and science knowledge, as measured by a standardized test. Further, this study is significant in its ability to help students better understand the social practices of science (i.e., sharing information and ideas via written language) and that science texts are open to interpretation, yet textual elements within the texts constrain the interpretations that can be made (Hand et al., 2003). Finally, this study adds support to the idea that separate science and reading comprehension instruction needs to traded for instruction that joins the two because science knowledge without reading comprehension will continue to yield students who are unable to pass state and national science achievement tests and ultimately be unable to live scientifically literate lives.

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APPENDIX

Table A-1

Studies in literature review

Study	Research design and population	Measures	Duration and Conditions	Results
O'Reilly & McNamara (2007)	Exploratory analysis Grades 9-12 n=1651 students	• Multiple-choice science knowledge test (α=.74) • Gates-MacGinitie(α=.95) • Metacomprehension Strategy Index (α=.72) • Science comprehension passage (Open ended questions, α=.87, multiple-choice questions, α=.83)	N/A	Science knowledge on: -Multiple choice *d*=0.51 -Open-Ended Comprehension, *d*=0.58 -Course Grade, *d*=0.20 -State Science Test, *d*=0.71 Reading Skill on: -Multiple choice *d*=0.64 -Open-Ended Comprehension, *d*=0.78 -Course Grade, *d*=0.25 -State Science Test, *d*=0.73 Comparison of skilled readers with low science knowledge and less skilled readers with higher science knowledge on: -Multiple choice *d*=0.14 -Open-ended passage comprehension, *d*=0.30 Reading skill for high knowledge students: -Multiple-choice *d*=0.94 -Open-ended *d*=1.01 -Grade *d*=.43 -State science *d*=0.81

Table A-1 (continued)

Study	Research design and population	Measures	Duration and Conditions	Results
Seifert & Espin (2012)	Quasi-experimental Grade 9-12 n=20 students with LD	-Reading fluency: 5 min to read passage aloud -Vocabulary knowledge: 5 min for vocabulary matching task -comprehension measure: 10 multiple choice questions	**Duration:** 4 sessions, one per condition 45 min/session **Conditions:** -Text-reading -Vocabulary knowledge -Text-reading and vocabulary knowledge -Control	Text-reading on: -Reading fluency ES=0.47 (compared to Vocabulary condition), ES= 0.97 (compared to control) Combined condition on: -Reading fluency ES=0.49 (compared to Vocabular condition), ES=1.04 (compared to control condition) Vocabulary condition on: -Reading fluency ES=0.53 (compared to control)
Cervetti, Barer, Drop, Pearson, & Goldschmidt (2012)	Classroom based random-assignment Grade 4 n=94 teachers	-Science understanding (α=.84/pretest, α=.81/posttest) -Science writing (inter-rater reliability= .85/pretest, .79/posttest -Science vocabulary (α=.46/pretest, .69/posttest -Reading comprehension (α=.77/pretest, .76/posttest)	**Duration** 40 sessions (4 investigations at 10 sessions each) **Conditions:** -Research developed integrated science-literacy unit on topic of light -Regularly used curriculum on topic of light	Science understanding *d*=.65 Science vocabulary *d*=.23 Science writing: -overall *d*=.40 -science concepts: *d*=.63 -vocabulary count *d*=.80 -evidence *d*=.33 -introduction *d*=.38 -clarity *d*=.43
Fang & Wei (2010)	Quasi-experimental Grade 6 n=2 teacher n=233 students	-Gates-MacGinitie Reading Test(GMRT) -curriculum-referenced science test (CRST) (α=.78) -academic year science grade(AYSG)	**Duration:** 22 weeks **Conditions:** -Inquiry-based science curriculum with reading (ISR) -Inquiry based science	ISR on: -GMRT vocabulary *d*=.23 -GMRT comprehension *d*=.22 -GMRT total score *d*=.22 -CRST *d*=.35 -AYSG *d*=.34

Table A-1 (continued)

Study	Research design and population	Measures	Duration and Conditions	Results
Boardman, Klingner, Buckley, Annamma, & Lasser (2015)	Multi-site cluster randomized trial Grades 6-8 n=9 teachers n=1074 students	- Gates-MacGinitie Reading Test(GMRT) - Reading and writing scale scores from state mandated test	**Duration:** School year **Conditions:** -Collaborative Strategic Reading (CSR) (full) -Collaborative Strategic Reading (CSR) (partial) -Business as usual	-GMRT comprehension *g*=.18 (full), *g*=.13 (partial) -State reading test *g*=.19 (full), *g*=.14 (partial) -State writing test *g*=.23 (full), *g*=.15 (partial)
Kukner & Orr (2015)	Qualitative n=16 preservice content area teachers (PST)	-semi-structured interviews	N/A	**Themes associated with PSTs with strong commitment to literacy:** -Expanded understandings of literacies -literacy routines as opportunities for thinking and learning -Clear connections to curriculum outcomes and relevant authentic assessments **Themes associated with PSTs less certain about role of literacy in teaching:** -inability to speak fluently about incorporating literacy into teaching -lack of metacognitive awareness on how to plan for literacy strategies -lack of awareness of need to model literacy strategies

Table A-1 (continued)

Study	Research design and population	Measures	Duration and Conditions	Results
Yore (1991)	Grades 6-12 n=215 science teachers	-Science and Reading Questionnaire	N/A	**Attitudes toward science reading instruction** *Strongly Agree= 7, Strongly Disagree=1* 1. A science teacher is obliged to help students improve their reading abilities (*M*= 5.87, *SD*= 1.06) 2. Science teachers should teach content and leave reading instruction to reading teachers (*M*= 2.73, *SD*= 1.79) 3. Knowing how to teach reading in science should be required for teaching certification (*M*= 5.00, *SD*= 1.07) 4. Science teachers should be familiar with the theoretical concepts of the reading process (*M*= 5.07, *SD*= 1.22) 5. Only teachers of English should be responsible for teaching reading in secondary schools. (*M*= 2.27, *SD*= 1.10) 6. Every science teacher should teach students how to read science materials (*M*= 5.80, *SD*= 0.78) 7. The primary responsibility of a science teacher should be to impart subject matter knowledge. (*M*= 3.53, *SD*= 1.19) 8. A science teacher should be responsible for helping students comprehend at an interpretive level as well as a literal level when they read. (*M*= 5.40, *SD*= 0.83)

Table A-1 (continued)

Study	Research design and population	Measures	Duration and Conditions	Results
Yore (1991)				9. Science teachers should help students learn to set purposes for reading and how to monitor their own success. (*M*= 5.27, *SD*= 0.96) 10. Science teachers should feel a greater responsibility to the content they teach than to any reading instruction they may be able to provide. (*M*= 5.00, *SD*= 1.25) 11. Teachers who want to improve students' interest in reading should show that they like to read. (*M*= 5.73, *SD*= 0.96) 12. It is not necessary for the reader to know the purpose for reading science text material. (*M*= 2.40, *SD*= 1.18) **Beliefs about models of reading, science texts, and science reading skills** *Strongly Agree= 7, Strongly Disagree=1* 1. The science text and the reader interact to invent new meaning not contained in the text or by the reader. (*M*= 4.23, *SD*= 1.23) 2. Prior science experience is required for science text reading to be more than just an exercise in memorization. (*M*= 4.68, *SD*= 1.41) 3. The reader brings the meaning to a science text which just stimulates the readers' understanding. (*M*= 4.13, *SD*= 1.00)

Table A-1 (continued)

Study	Research design and population	Measures	Duration and Conditions	Results
Yore (1991)				4. While comprehending a new science concept from reading, most readers relate text information to familiar examples in their memory. (*M*= 5.01, *SD*= 1.31) 5. The science text contains all the information needed by the reader to understand the idea or concept. (*M*= 2.39, *SD*= 1.21) 6. Students require no background on a topic to read and comprehend text on that topic. (*M*= 2.87, *SD*= 1.21) 7. Most texts for secondary science are written at or below grade level for which they are intended, as judged by readability formula. (*M*= 3.52, *SD*= 1.43) 8. Sentence and paragraph structure in science textbooks must necessarily be different from that of other texts. (*M*= 3.73, *SD*= 1.58) 9. Students who can read non-science texts at their grade level will have no trouble reading science texts. (*M*= 4.93, *SD*= 0.96) 10. The problem with poor readers is that they do not follow the logical structure of paragraphs. (*M*= 4.67, *SD*= 0.72) 11. The ability to predict upcoming text can be used to distinguish between good and poor readers. (*M*= 4.87, *SD*= 0.99)

Table A-1 (continued)

Study	Research design and population	Measures	Duration and Conditions	Results
Yore (1991)				12. Titles and headings in a text are useful for effective reading comprehension. (*M*= 6.27, *SD*= 0.59) 13. Technical vocabulary should be introduced to students in content classes before they meet those terms in a reading passage. (*M*= 4.40, *SD*= 1.55)

Table A-2
TEKS Used in Science Knowledge Assessment

TEKS #	Texas Essential Knowledge and Skills description	Number of questions
6.11b	(11) Earth and space. The student understands the organization of our solar system and the relationships among the various bodies that comprise it. The student is expected to: *(B) understand that gravity is the force that governs the motion of our solar system;*	1
6.12d	(12) Organisms and environments. The student knows all organisms are classified into Domains and Kingdoms. Organisms within these taxonomic groups share similar characteristics which allow them to interact with the living and nonliving parts of their ecosystem. The student is expected to: *(D) identify the basic characteristics of organisms, including prokaryotic or eukaryotic, unicellular or multicellular, autotrophic or heterotrophic, and mode of reproduction, that further classify them in the currently recognized Kingdoms;*	1
6.5c	Matter and energy. The student knows the differences between elements and compounds. The student is expected to: *(C) differentiate between elements and compounds on the most basic level;*	1
6.6a	Matter and energy. The student knows matter has physical properties that can be used for classification. The student is expected to: *(A) compare metals, nonmetals, and metalloids using physical properties such as luster, conductivity, or malleability;*	1
6.6b	Matter and energy. The student knows matter has physical properties that can be used for classification. The student is expected to: *(B) calculate density to identify an unknown substance; and*	1
6.8a	Force, motion, and energy. The student knows force and motion are related to potential and kinetic energy. The student is expected to: *(A) compare and contrast potential and kinetic energy;*	2
6.8c	Force, motion, and energy. The student knows force and motion are related to potential and kinetic energy. The student is expected to: *(C) calculate average speed using distance and time measurements;*	2
6.8d	Force, motion, and energy. The student knows force and motion are related to potential and kinetic energy. The student is expected to: *(D) measure and graph changes in motion;*	2
6.9c	Force, motion, and energy. The student knows that the Law of Conservation of Energy states that energy can neither be created nor destroyed, it just changes form. The student is expected to: *(C) demonstrate energy transformations such as energy in a flashlight battery changes from chemical energy to electrical energy to light energy.*	2
7.10b	(10) Organisms and environments. The student knows that there is a relationship between organisms and the environment. The student is expected to: *(B) describe how biodiversity contributes to the sustainability of an ecosystem;*	1
7.10c	(10) Organisms and environments. The student knows that there is a relationship between organisms and the environment. The student is expected to: *(C) observe, record, and describe the role of ecological succession such as in a microhabitat of a garden with weeds.*	1

Table A-2 (continued)

7.11a	Organisms and environments. The student knows that populations and species demonstrate variation and inherit many of their unique traits through gradual processes over many generations. The student is expected to: *(A) examine organisms or their structures such as insects or leaves and use dichotomous keys for identification;*	1
7.11c	Organisms and environments. The student knows that populations and species demonstrate variation and inherit many of their unique traits through gradual processes over many generations. The student is expected to: *(C) identify some changes in genetic traits that have occurred over several generations through natural selection and selective breeding such as the Galapagos Medium Ground Finch (Geospiza fortis) or domestic animals.*	1
7.12b	(12) Organisms and environments. The student knows that living systems at all levels of organization demonstrate the complementary nature of structure and function. The student is expected to: *(B) identify the main functions of the systems of the human organism, including the circulatory, respiratory, skeletal, muscular, digestive, excretory, reproductive, integumentary, nervous, and endocrine systems;*	2
7.12d	(12) Organisms and environments. The student knows that living systems at all levels of organization demonstrate the complementary nature of structure and function. The student is expected to: *(D) differentiate between structure and function in plant and animal cell organelles, including cell membrane, cell wall, nucleus, cytoplasm, mitochondrion, chloroplast, and vacuole;*	1
7.12f	(12) Organisms and environments. The student knows that living systems at all levels of organization demonstrate the complementary nature of structure and function. The student is expected to: *(F) recognize that according to cell theory all organisms are composed of cells and cells carry on similar functions such as extracting energy from food to sustain life.*	1
7.14b	(14) Organisms and environments. The student knows that reproduction is a characteristic of living organisms and that the instructions for traits are governed in the genetic material. The student is expected to: *(B) compare the results of uniform or diverse offspring from sexual reproduction or asexual reproduction;*	
7.14c	(14) Organisms and environments. The student knows that reproduction is a characteristic of living organisms and that the instructions for traits are governed in the genetic material. The student is expected to: *(C) recognize that inherited traits of individuals are governed in the genetic material found in the genes within chromosomes in the nucleus.*	1
7.5c	(5) Matter and energy. The student knows that interactions occur between matter and energy. The student is expected to: *(C) diagram the flow of energy through living systems, including food chains, food webs, and energy pyramids*.	1
7.6a	(6) Matter and energy. The student knows that matter has physical and chemical properties and can undergo physical and chemical changes. The student is expected to: *(A) identify that organic compounds contain carbon and other elements such as hydrogen, oxygen, phosphorus, nitrogen, or sulfur;*	2
7.7a	(7) Force, motion, and energy. The student knows that there is a relationship among force, motion, and energy. The student is expected to: *(A) contrast situations where work is done with different amounts of force to situations where no work is done such as moving a box with a ramp and without a ramp, or standing still;*	2
7.8c	(8) Earth and space. The student knows that natural events and human activity can impact Earth systems. The student is expected to: *(C) model the effects of human activity on groundwater and surface water in a watershed.*	1

Table A-3

Timeline of Intervention Activities

Date	Activity						
October	Professional development day 1						
October	Professional development day 2						
November 2, 2018	Pretest						
Intervention							
Week	Class visit	Classroom Activities	Intervention activities	Teacher use of text structure intervention	Researcher use of text structure intervention	Researcher modeled lesson	Text structure appropriate lesson
1 Nov27-Dec 1	1-5	-Students drew pictures of germinated pinto beans and answered questions about changes in the beans.	-Suggestion to use comparison matrix to highlight differences between the beans and facilitate making inferences related to the differences. Teacher rejected idea stating students made comparisons visually and did not need to write them down	N	Y	N	Y
	6	-Describe plants with high and low turgor pressure. -Students compared potatoes soaked in plain and salt water. Used "Venn diagram"	-Students given intervention adapted text and organizer to read and complete silently. Teacher did not model for students. (*previous lesson)* -Suggestion that teacher work *with* and model for students when using text structure before giving as independent activity - Suggestion to use comparison matrix was rejected because teacher "needed them to describe it". -Suggestion to use matrix instead of Venn diagram. Helped students create matrix. Used cause and effect language to help students see differences.	N	Y	N	Y
	7	-Text on turgor pressure	-Modeled lesson -Discussed ways to use text structure in class -created organizer for next text	N	Y	Y	Y

Table A-3 (continued)

1 Nov27-Dec 1	8	-Turgor pressure potato lab	-Teacher created comparison matrix for potatoes based on suggestion -Comparison words and cause and effect words used during lab	N	Y	N	Y
	9	-Notes on stimulus and response	-Teacher used cause and effect words to make explicit the relationship between stimulus and response -Supported teacher use of cause and effect to explain stimulus and response	Y	Y	N	Y
2 Dec 4-8	1-2	-Oral notes on homeostasis	-Teacher uses cause and effect words -Showed students how to use text structure with high stakes test questions	Y	Y	Y	Y
	3	-Notes on homeostasis	-Use of cause and effect words and cause and effect chart -Showed students how to use text structure with high stakes test questions	Y	Y	Y	Y
	4-5	-Notes on homeostasis	-Modeled using of text structure -Showed students how to use text structure with high stakes test questions	Y	Y	N	Y
3 Dec. 11-15	1-8	-Genetics	-Modeled text structure lesson -Teacher used class period to grade	N	Y	Y	Y
	9, 12	-Genetics	-Used cause and effect to explain Punnett squares to students	N	Y	N	Y
	10-11, 13-14	-Genetics	-Modeled use of text structure intervention to help with genetics	N	Y	Y	Y

Table A-3 (continued)

4 Jan. 8-12	1-2, 4	-Review of school rules and lockdown procedure		N	N	N	N
	3	-Genetics quiz	-Helped students identify the signaling words in quiz questions and how those could help with answering questions	N	Y	N	Y
	5	-Organizer for reproduction	-Suggested that students use a comparison matrix for sexual and asexual reproduction	N	Y	N	Y
	6	-Review of comparison activity from previous day -Animal adaptation notes	-Modeling of text structure and writing main idea	Y	Y	Y	Y
	7	-Animal adaption notes	-Modeling of text structure and writing main idea	Y	Y	Y	Y
5 Jan 16-10	No observations due to testing						
6 Jan 22-26	1	-Warm up question -animal adaption notes	-Suggestion of answering warm up question using cause and effect structure -Suggestion of using cause and effect statements rather than coping notes verbatim	N	Y	N	Y
	2	-Animal adaptation notes	-Teacher using text structure and modeling for students -Teacher asks students to identify the cause and the effect -Students wrote main idea using cause and effect stem	Y	N	N	Y

Table A-3 (continued)

	3, 4	-Warm up question -Animal adaptations	-Worked with students on writing main idea using cause and effect stem -Worked with students on using cause and effect to make inferences	Y	Y	Y	Y
7 Jan 29-Feb 2	1	-Warm up question -Dichotomous key	-Suggested that students answer warm up using cause and effect structure -Dichotomous keys do not support use of text structure intervention	N	Y	N	N
	2-3	-Dichotomous key	-Dichotomous keys do not support use of text structure intervention	N	N	N	N
	4	-warm up question -Dichotomous key	-Teacher used cause and effect signaling words to help students with warm up question -Dichotomous keys do not support use of text structure intervention	Y	N	N	N
	5	-dichotomous key	-Dichotomous keys do not support use of text structure intervention	N	N	N	N
	6-7	-warm up question -Stations about dichotomous keys	-Suggested that students use the signaling words in the question to better understand what the question was asking -Helped students apply text structure to the various stations as appropriate	N	Y	N	Y
	8	-warm up questions -notes on natural selection	-warm up and notes are based on recitation of memorized information and not appropriate for text structure intervention	N	N	N	N
	9	-Finishing text from previous day	-Reminded students to use the cause and effect stem when writing the main idea of the passage	N	Y	N	Y

Table A-3 (continued)

	10	-Dichotomous key	-Dichotomous keys do not support use of text structure intervention	N	N	N	N
8 Feb 5-9	1	-Test review	-Explained to students how most questions were written using cause and effect and if students wrote answer using cause and effect structure they would better remember the information	N	Y	N	Y
	2	-warm up question -test review	-Helped students set up comparison matrix for warm up question -Explained to students how most questions were written using cause and effect and if students wrote answer using cause and effect structure they would better remember the information	N	Y	N	Y
	3	-Comparison of sexual and asexual reproduction -Test review	-Teacher is not using matrix for sexual and asexual comparison. -Explained to students how most questions were written using cause and effect and if students wrote answer using cause and effect structure they would better remember the information	N	Y	N	Y
	4, 5	-Warm up question -Test review	-Explained that both warm up questions were causes and effect and should be answered as such -Explained to students how most questions were written using cause and effect and if students wrote answer using cause and effect structure they would better remember the information.	N	Y	N	Y
9 Feb 12-15	1, 3, 5	-Energy web	-Teacher mentioned that previous lesson using comparison text went well because students understand the format -Teacher uses cause and effect signaling words to discuss changes in food web. Students are asked to identify the cause and the effect	Y	Y	N	Y

Table A-3 (continued)

	2	-Energy web	-Teacher does not use signaling words to explain energy web.	N	N	N	Y
	4	-Fill in the blank notes	-Students completed comparison matrix over producers, consumers, and decomposers independently (*previous lesson).* Teacher had not gone over comparison or given it back to students. -Attempted to help students with notes but fill the blank format made text structure intervention was not easily applied	N	Y	N	N
10 Feb 19-23	1-5	-Creating a food for ecosystem of choice	-Encouraged students to think about how the ecosystem would affect the type of animals that live there	N	Y	N	Y

Figure A-1
Semi-scripted lesson plan

Adaptations Lesson Plan

1. Tell students that this text is cause and effect and as they read they will need to think about what the causes are and what the effects are. Specifically, they need to think about adaptations as a cause and what the effects of those adaptations might be.
2. Read article **WITH** students and point out the cause/effect signaling words (highlighted in teacher text). Work with students to fill in graphic organizer as you read, making sure students understand how the cause/effects are related. For example, give students the cause and ask them to state what the effect is.
3. Discuss with students what the major **cause** being discussed in each section is and what the major **effect** of that cause is. Have students write the main idea for each section using the cause and effect main idea pattern (The cause is _____ and the effect is _____).
4. Discuss with students how the three causes work together to create a main effect. Have students write the main idea for the whole passage using the cause and effect main pattern.
5. Have students answer inference questions based on information in the text and using the cause and effect organization to help them in making those inferences.

Adaptations Graphic Organizer (Teacher copy)

CAUSE		EFFECT
Behavioral Adaptations		
Heron raises wings to block out sun's glare	→	Easier for heron to see prey
Behavioral adaptations	→	Organisms have behaviors that support survival and reproduction
Fish not knowing how to swim	→	Would probably die
Wolf not learning to hunt	→	Would probably die before reproducing
Structural Adaptations		
Birds have light bones	→	Easier to fly
Fish have gills	→	Breathe underwater
Structural adaptations	→	Physical characteristics that support survival
Physiological Adaptations		
Oyster's ability to make shell	→	Body is protected from injury and predators
Physiological adaptation (biochemical function)	→	Organism is better suited to environment
Human's ability to maintain constant internal body temperature	→	Live in a variety of climates
Structural, physiological, and behavioral adaptations work together	→	Organism's survival
Lion's sharp teeth claws, ability to stalk prey, and ability to grow sharp teeth and claws	→	Lion is well suited to hunting large animals, more likely to survive

Figure A-1 (continued)

Main Idea (Teacher Copy)

The main idea of a text tells the topics that were discussed in the text, how the topics were discussed (text structure) and what was discussed about the topics. Write a main idea sentence about the article using the **cause and effect** pattern.

Cause and Effect Main Idea Sentence Stem

The main cause is ___________________, and the main effect is ___________________________.

Write your main idea sentence here:

The cause is behavioral adaptations. The effect is an organism has behaviors that help it survive.

The cause is structural adaptation. The effect is an organism has physical characteristics that help it survive.

The cause is physiological adaptations. The effect is an organism has biochemical functions that help it survive.

The causes are behavioral, structural, and physiological adaptations that support an organism's survival. The effect is the adaptations that helped with survival are passed on AND the population survives.

Inference questions:

1. Kangaroo rats live in the desert. Their kidneys can produce very concentrated urine to conserve water. What is the effect of the rats' ability to produce concentrated urine? How do the rats' internal structures function to help it survive its environment?
2. How does the human behavioral adaptation of language help us to survive?
3. A snake's venom is a physiological adaptation. How does this adaptation support the survival of venomous snakes?
4. Why do behavioral, structural, and physiological adaptations vary across species of animal?
5. In the far north, near the artic, there are artic hares that are tan in the spring and white in the winter. How do you think this physiological adaptation helps the hare survive?

6. A population of grasshoppers lives in a field of green grass. Some of the grasshoppers are dark brown and some are green. Which grasshoppers are more likely to be prey for birds?
7. What is likely to happen to the grasshopper population over several generation?