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Leveraging Writing Routines To Increase Achievement Of English Learners In Science

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LEVERAGING WRITING ROUTINES TO INCREASE ACHIEVEMENT OF ENGLISH LEARNERS IN SCIENCE

by

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CHAPTER ONE: Introduction

Fifty Bugs and a Fifth Grader

One of my 5th grade students volunteered her time during recess to help me organize science materials for my mainstream science class. The isopods and darkling beetles had arrived in the mail, and they needed to be sorted into smaller containers. After this task was done, my student—a difficult-to-engage, female, Somali English learner (EL)—lingered until recess was over. She gingerly played with the beetles in the palm of her hand, her eyes bright with curiosity and excitement. “How can you tell if they are boys or girls? How big do they grow? Can they talk to each other? I want to know what they are thinking!”

Hopeful that I could leverage her ebullient enthusiasm to engage her in reading (one of her primary avoidances), I developed a lesson around an article from the curriculum that would begin to address her questions. To my disappointment, she lost interest in the article quickly. As the life science unit progressed, her answers to formative assessments lacked depth of knowledge even though she was engaged in the unit’s hands-on activities. This underachievement occurred despite my efforts to mitigate language barriers by utilizing best-practice pedagogy in science for ELs. Strategies such as cooperative learning groups, hands-on activities, explicit teaching of vocabulary, modeling of concepts, and use of thinking stems to support oral language for discussions worked with my English learners in math. Why was I not getting better results in science?

What could I do differently that would enable her, and others like her, to consolidate her understanding of scientific concepts, as well as strengthen her developing language skills? These observations and questions have led me to the topic investigated in this paper: Can targeted writing tasks and teacher feedback deepen and refine ELs' scientific knowledge while at the same time support their acquisition of language skills?

My Background

I bring to this capstone thesis 18 years of classroom-related experience. Seventeen of those years have been in elementary settings in one public school district in a diverse, second-ring suburb of a large Midwestern city. Of the 17 years, 15 have been as a classroom teacher of Grades 2, 3, 5 and 6.

Ten years into my teaching career, I completed the requirements for a second credential, English as a Second Language (ESL). I continued to serve as a mainstream teacher until two years ago when an ESL position in my district became available. Budget cuts led to a rare opportunity to teach ESL half-time in one school and mainstream math and science in another school. This current school year, I am serving as a full-time ESL teacher in the same two schools at the elementary level.

My Role as a Researcher

My experiences as both a mainstream classroom and ESL teacher have led me to seek answers to my research topic that would be applicable in both settings. The conclusions gleaned from this study can be used by both mainstream and ESL teachers, independently or in conjunction with one another. The knowledge gained would benefit both ELs and non-ELs.

Having served as a mainstream classroom teacher in multiple grades and in different buildings, I know the curriculum, the standards, the pace of a school day and general classroom dynamics. I have a good sense as to which ideas have a likelihood of success and which do not. As an ESL teacher, I know the students' needs, the role their home languages play in learning English, cultural backgrounds, and the complexities of academic language. I have a good sense of strategies that can help them learn mainstream content. These perspectives focused my interest on investigating reasons why many ELs, such as my 5th grader, have difficulties in science, and formulating practical solutions for both mainstream and ESL teachers.

Research That Shaped This Study

The literature provides insight on the elements of my research topic. The abstract nature of science and the language it employs pose unique challenges for students (Christie & Derewianka, 2008), especially ELs (Aguirre-Muñoz, Park, Amabisca & Boscardin, 2009; Echevarría, Vogt & Short, 2010; Lee, 2012). Teaching and supporting students in their acquisition of academic language requires understanding of its complexities as well as intentional planning and instruction (Zwiers, 2014; Zwiers, O'Hara & Pritchard, 2014). Science is a meaningful context in which to incorporate writing, especially when utilizing a science notebook in an inquiry setting (Klentschy, 2005). Science notebooks can be used to evaluate student understanding of scientific concepts and writing skills (Ruiz-Primo, Li, Ayala & Shavelson, 2004). However, to improve skills and understanding, students require quality feedback (Lee, Penfield & Buxton, 2011). The literature led me to speculate about the ways that students can receive quality feedback from teachers and how this feedback might impact student learning.

Formulation of a Hypothesis

My teaching experience focused my interest on ways that would allow students to discuss the feedback they receive with a teacher. My experience with elementary-aged students is that they need to be taught how to use the feedback they receive on assignments, especially written assignments. I have found value in meeting one-on-one or in small groups with students to coach them in their revisions of writing products created in language arts. Sometimes they do not understand written feedback, and a conversation or a mini-lesson clarifies misconceptions. Sometimes our conversations are brief, and students only require the opportunity to integrate new learning through revising. These coaching opportunities, often referred to as writing conferences, allow me to differentiate to a high degree. I see each student's strengths, challenges and growth.

Having experienced the benefits of writing conferences, I wondered what the impact would be if ELs, after writing about a scientific concept, conferenced with teachers about science content and writing skills, and then revised their writing according to the feedback. Would these extra steps increase their achievement in science? I hypothesized that it would.

Research Questions

This study investigates how quality feedback, when paired with conferencing and opportunities to write, can consolidate scientific knowledge, accelerate the acquisition of academic language of science, and support the writing-skill development of elementary ELs. To determine if this hypothesis is valid, I conducted research to answer these specific questions:

1. How are 5^{th} grade ELs' performances on an objective portion of a science quiz on erosion and deposition affected after discussing concepts with a teacher and writing about these concepts?
2. How are 5^{th} grade ELs' written explanations of erosion and deposition and use of genre-specific language structures affected after conferencing with a teacher about these concepts?

With the knowledge gained from this investigation and leveraging the natural curiosity students bring to science, I hope to help students demystify the unique challenges of the language of science while simultaneously acquiring the English they need for success.

Overview of Chapters

This first chapter served as a brief introduction to the motivation of this study, my background as a researcher, my role as such, the questions that guided my research, and my research questions. In Chapter Two, I present a review of the literature. I describe the unique challenges that the academic language of science poses to ELs and how it can be mitigated. I show how writing can be used in science contexts and how quality teacher feedback is necessary to improve student performance. Chapter Three provides the methodology for this qualitative study along with the rationale. It includes general information about the participants and setting, specific information about data collection techniques, the pilot study, and a description of scoring rubrics, testing, and treatment procedures. Chapter Four presents the results of this study along with an analysis of the data collected. Chapter Five summarizes the conclusions of this study and discusses the implications of the findings, as well as its limitations.

CHAPTER 2: Literature Review

Introduction

The purpose of this capstone is to investigate how writing in science contexts can help ELs consolidate their understanding of scientific concepts, foster their acquisition of academic English, and provide additional practice in writing. Specifically, I seek to answer two related questions: How are 5^{th} grade ELs' performances on an objective portion of a science quiz on erosion and deposition affected after discussing these concepts with a teacher and writing about these concepts? How are 5^{th} grade ELs' written explanations of erosion and deposition and use of genre-appropriate language structures affected after conferencing with a teacher?

This review of literature begins by defining science literacy and by showing how ELs are achieving in science nationally and at the state level. The review continues by describing the uniquely challenging characteristics of the language of science and discusses best practices for teaching academic language. Next, writing as part of science investigations is presented as a meaningful context to target and develop science concepts, academic language and writing skills. The final topic covers strategies that teachers can use to provide quality feedback to students about their scientific knowledge, academic vocabulary and writing skills.

Science Literacy and ELs

No matter the cultural context, people throughout history have sought to understand natural phenomena and how these phenomena influence human activity (Aikenhead & Ogawa, 2007). While the purpose and style of systematic documentation have varied, there is a general acknowledgement that understanding natural phenomena—science—informs human decisions. These decisions can be small and large. Small, humorous examples abound from my experiences hosting family visiting from a warmer climate during a Minnesota winter. In one such instance, I had to explain to my mother the science behind why the outside windows she attempted to clean in subzero temperatures appeared icy and cloudy.

Understanding science also influences important decisions, such as choosing between medical procedures, or voting on important legislation that can affect the environment and the economy (Glynn & Muth, 1994; Lederman, 2014; National Research Council, 1996). Even understanding the most basic concepts can serve as a foundation in the search for deeper understanding. Science literacy is foundational.

Science Literacy for All

The National Science Education Standards (NSES) describe science literacy as "knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs and economic productivity" (National Research Council, 1996, p. 22). The NSES describe how scientifically literate people are able to understand natural phenomenon of everyday life and can determine answers to questions from everyday experiences. Aikenhead and Ogawa (2007), recognizing that science in the United States is rooted in cultural values and assumptions, argue for a definition of science that could include multi-science processes and products generated in other cultures. They explain that there are other ways of knowing the natural world that may not fit nicely in the boundaries of the scientific method. They affirm that science is "a rational empirically based way of knowing nature that yields, in part, descriptions and explanations of nature" (p. 544).

Notable science organizations promote a science-for-all philosophy. Each individual, regardless of background, is entitled to a quality science education (American Association for the Advancement of Science, 2017; National Research Council, 1996; Next Generation Science Standards Lead States, 2013). This inclusion validates the advancements that have come from a widely diverse scientific community and recognizes the potential for future contributions from next generations. Part of this next generation are ELs who now make up nearly 10% of our nation's student population (U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, 2017). To engage them in science brings benefits to all; however, research has shown that this group has not fared well in meeting science standards of achievement.

Standardized Testing of ELs and Former ELs in Science

Measures of standardized tests indicate that ELs lag in science achievement nationally and on the state level.

National performance. *The Condition of Education 2017* is a congressionally-mandated report that is published annually (U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, 2017). It offers nation-wide data from reading, math and science tests as obtained from results from the National Assessment of Educational Progress (NAEP). The NAEP science test is administered to

4^{th}, 8^{th}, and 12^{th} graders every four years. Longitudinal comparisons are made between data points. In 2015, there was a 36-point achievement gap between EL and non-EL 4^{th} grade students. The gap in 8^{th} grade was 46 points. In 12^{th} grade it was 47 points. The gap between these two groups has remained stagnant overall, although there has been a 3-point narrowing of the gap in 4^{th} grade since 2009.

An issue with this report is that the data lack nuance. They do not indicate how long ELs have been classified as English learners. It is possible that some students who were classified as ELs as 4^{th} graders in 2009 also took the test as 8^{th} graders in 2013. In this case, we could use this data to underscore the need to improve science education for ELs. It is also possible that students who were ELs in 2009 were no longer classified as ELs in 2013, and that new ELs have replaced them. To acknowledge the role that limited language plays in ELs' ability to perform well on standardized tests is a fair concession. It stands to reason that ELs have not yet acquired the language needed to decipher questions and answer appropriately. One can surmise that given enough time they will score as well as their peers. Data from the Minnesota Department of Education can shed a different light on this supposition.

State performance. *The English Learner Education in Minnesota* report is published by the Minnesota Department of Education to inform stakeholders of the laws, resources and demographic trends regarding ELs in Minnesota (Minnesota Department of Education, Division of Student Support, 2016). According to the report, ELs are the fastest growing student population in Minnesota with the largest influx of learners in Hennepin county.

ELs scored significantly lower on all Minnesota Comprehensive Assessment (MCA) tests as compared to their non-EL counterparts. The MCAs test students in reading, math, and science. Setting aside comparisons between ELs' and non-ELs' test scores, another insight into the data can be gleaned by analyzing the discrepancy of EL performance on these different tests. In 2016, 16.9% of ELs scored as proficient or distinguished in reading. In math, 23.2% did. However, in science only 10.1% scored as proficient or distinguished. Accommodations for technology allow for test questions to be read to all students on science and math tests; this accommodation is not allowed on the reading test. ELs scored roughly 13 points lower on the science test than on the math test that used the same accommodation. Surprisingly, ELs scored six points lower on the science test than the reading test.

Some may argue that math and reading are prioritized over science in schools. Because science is less emphasized, the lower science scores could result in a score discrepancy. While science scores for all students do trend lower than math and reading, the discrepancy is larger for those whose primary home language is a language other than English. Statewide 2017 achievement data show that students whose home language was declared as English scored 62.5% proficient in math, 64.4% in reading, and 58.5% in science. That is a difference of 4 percentage points between the math and science tests that utilize accommodations for all learners. For students who were former ELs prior to 2017, but were no longer classified as such in 2017, 45.1% were proficient in math, 47.8% were proficient in reading and 33% scored proficient in science. The discrepancy between the math and science scores is 12.1 percentage points. The research identifies academic language as a significant factor for this discrepancy in achievement.

EL Science Achievement Gap: A Potential Explanation

Some have reasoned that since language barriers prevent ELs from performing well on standardized tests, testing accommodations could mitigate these barriers. A 2009 study found that these accommodations led to insignificant gains on the performance outcome of tested students (Kieffer, Lesaux, Rivera & Francis, 2009). Kieffer et al. analyzed ELs' scores from various tests that provided accommodations such as increasing the allotted testing time, providing bilingual glossaries, simplifying the English of testing items, and administering tests in students' home languages. They found that the largest gain was a 10% increase from the use of bilingual glossaries. The researchers explain that this accommodation is only effective for students who already have some education in their home language. These students have the best chance to translate words based on their understanding of the concepts they learned in their home languages. The use of glossaries does not help the large portion of ELs in the United States who have not already been educated in their home language.

The researchers conclude that the reason for ELs' low performance on standardized tests was a lack of academic language in the content areas. In their words, "To meet high standards for academic success, these learners require targeted, explicit, and intensive instruction in the complex and specialized language that lies at the heart of each content area" (Kieffer et al., 2009, p. 1190). This is not to say that if all ELs receive targeted, explicit, and intensive instruction in the language of science that they will perform on par with non-ELs on standardized tests. Lee et al. (2011) found that if instruction is presented in English, even with specialized targeted interventions, there is limited success for students at the beginning and intermediate proficiency levels. Students who had higher English proficiencies showed the greatest gain in science understanding and acquisition of academic language.

The conclusion to be drawn from these two studies is not that ELs are incapable of learning academic English and science concepts. On the contrary, these studies show that beginning ELs need time to develop enough command of English and the language of science to in order to demonstrate what they know. At the upper-intermediate to advanced levels, students will show greater achievement gains if academic language and science concepts are specifically targeted. It is important that science instruction be available to all levels of ELs regardless of their ability to demonstrate their scientific knowledge.

This first section of the literature review shows how ELs underperform in science compared to their non-EL counterparts. One possible explanation for this discrepancy is that ELs require targeted instruction in the academic language of science. This next section will discuss current research on how to accomplish this.

Academic Language

The importance of teaching academic language has received increasing attention in education circles; however, there remains confusion as to what it is (Lee, Quinn & Valdés, 2013). Some educators are unaware of the multi-faceted nature of language and confuse the broad category of academic language with academic vocabulary. For example, with the adoption of Common Core State Standards in English Language Arts across the nation, more educators are being made aware of three tiers of words (Beck, McKeown & Kucan, 2013; *Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science and Technical Subjects: K-5*, 2010). Tier 1 words are words of everyday speech. Tier 2 words reach across different disciplines (e.g. analyze, determine). Tier Three words are academic words that are particular to one discipline (e.g. DNA, orbital). Some teachers, now familiar with the tiers of vocabulary, think that by teaching this vocabulary they have met the needs of children with diverse language backgrounds. Academic language is not just vocabulary. It is much more (Lee et al., 2013).

Academic Language Defined

A definition that incorporates the multi-faceted nature of academic language is penned by Zwiers. Academic language is "the set of words, grammar, and discourse strategies used to describe complex ideas, higher-order thinking processes, and abstract concepts" (2014, p. 22). Academic language is the culmination of language on three levels: word, sentence and whole text/discourse.

Further, each content area has its unique vocabulary and thinking processes for communication. The manifestations of these thinking processes are seen in sentence content and structure; e.g. in science, it is more appropriate to make objective observations; sharing personal feelings about one's experience has less value (Christie & Derewianka, 2008). Discourse that occurs within each discipline has different purposes. The existence of different genres reflects these purposes (Christie & Derewianka, 2008). Academic language at the word, sentence and discourse level in *each* content area must be explicitly taught (Aguirre-Muñoz et al., 2009).

The Unique Challenges of the Language of Science

The language of science carries unique challenges. Christie and Derewianka (2008) quantified some of these differences using writing samples from students from various school ages and across content areas. Analyzing the samples with a Systemic Functional Linguistics (SFL) lens, they found certain characteristics of academic language in different disciplines (i.e. nominal groups; frequency, type and position of dependent clauses; lexical density; and cohesion of ideas).

While these distinct characteristics were found across genres and content areas and were found to increase in complexity as students advanced in school, science posed greater challenges compared to the other genres they investigated. The language of science has a higher lexical density (Christie & Derewianka, 2008). Lexical density is a value calculated from the number of content words divided by the total number of words in a phrase. A higher lexical density poses more challenges for comprehension and expression.

Another reason why the language of science is more difficult is that science is hierarchical in its knowledge structure. Hierarchical knowledge structures build upon previous knowledge. As such, the concepts are abstract, and the language is specialized. The effect is that those who are not familiar with the structures are alienated (Christie & Derewianka, 2008; Christie & Martin, 2007; Halliday & Martin, 2004).

These are significant challenges unique to science. Research has identified best practices to bridge the everyday-language to language-of-science divide.

Best Practices in Teaching Academic Language to ELs

There are numerous variables that affect student learning. Consequently, there are numerous strategies to support ELs' academic language acquisition. The following are frequently mentioned in the literature.

High standards with high support. Educators must maintain high standards for ELs. Providing access to content is not enough. ELs must be taught in such a way so as to *own* the language (Zwiers et al., 2014).

A powerful reality of student achievement is that it is tied to teachers' expectations of them (Brophy & Good, 1970). It is imperative for teachers to examine their expectations of ELs and to hold them to high standards. While the language they use may not be perfect, ELs can fully participate in science with targeted support (Lee et al., 2013).

Zwiers et al. (2014) advocate for carefully crafted lessons based on Common Core standards that require higher-order thinking and tasks that have relevant purposes. These authors suggest a framework for teachers: select complex texts, create authentic and meaningful ways for students to produce complex output, and foster academic interactions. By purposely structuring lessons with these three components, the rigor intensifies, and academic language is rehearsed to a degree that students can *own* it.

Supported academic discussions. Zwiers (2014) is strong proponent of academic discussion as a means to support content learning. Emphasizing process over product, he advocates for teachers to build students' academic collaboration skills, which include "elaborating and probing meaning, reasoning together, analyzing problems together, comparing possible solutions and ideas together, and making decisions together" (2014, p. 155). Through the collabroation process, students utilize academic language to discuss higher-order thinking tasks, and this in turn builds new academic knowledge and skills. Zwiers (2014) further explains that academic collaboration skills are best built in small groups or pairs versus whole-class discussions. A setting where students work in small groups or pairs offers more opportunity for students to talk about content, and it is less intimidating for students of diverse language backgrounds to participate. However, teachers must teach and scaffold academic collaboration skills. Quoted directly in the following bulleted list, Zwiers recommends that group tasks should:

- Be content-based and integrated with a broader curriculum topic.
- Have a clear outcome and an authentic and engaging purpose.
- Challenge students to use higher-order thinking skills.
- Involve all learners in the group to share in the task and its language.
- Encourage cooperation, rather than competition, between partners and groups.
- Recycle academic terms and grammatical ways of connecting ideas.
- Require students to bridge information gaps in order to accomplish a task. (2014, p. 157)

Even with the best thought-through tasks, students will still require training through modeling and practice, and this training may take years (Zwiers, 2014). School systems should think through how academic collaboration skills are best developed through the grade levels.

Hands-on science context. Inquiry-based science learning can have beneficial outcomes for ELs across content areas (Amaral, Garrison & Klentschy, 2002). There are several reasons why this might be so. In an inquiry-based classroom, students have time to explore, discuss, and construct their understanding through hands-on experiences. Students can learn from each other and extend their knowledge. Inquiry activities have less language load, and students are freed to refine concepts. In a cooperative learning setting, students are able to interact with peers and to get help from peers who might share the same language. Inquiry also allows for more questions, and affective filters are lowered. Inquiry-based science fosters a sense of accomplishment and success when students figure out answers to questions or problems. When teachers strategically incorporate language experiences that specifically target academic language, the result benefits students from diverse language backgrounds (Amaral et al., 2002; Klentschy, 2005; Lee & Buxton, 2013; Moses, Busetti-Frevert & Pritchard, 2015). Integrating language and content is beneficial for all students, especially ELs (Lee, 2012; Lee et al., 2013). The specific ways that language can be integrated and promoted in a science context are numerous. See Appendix A for examples.

Cultural backgrounds and school science. One less salient facet that may affect ELs' achievement in science is that the school science curriculum and programming can be in conflict with some home cultures (Lee, 2002). These incongruities may take several forms. For instance, some cultures do not encourage questions and inquiry, a key feature in many science curricula. If teachers recognize that a lack of participation in the inquiry process might be because of culture backgrounds, teachers will want to model how to ask questions until students are trained in the process.

Another way that science and home cultures may be in conflict is in the expectations of self-directed learning and autonomy. Some students' home cultures are highly structured, and students do only what authorities direct them to do. In science, teachers ideally want students to be independent and display a level of autonomy in finding answers to questions (Lee, 2002). Teachers might need to begin with more structure and lead students to more independence.

A third area of possible cultural incongruity is the balance between working collaboratively and independently. Many cultures value collaboration; however, in the science classroom, it is important for students to be able to complete tasks independently (Lee, 2002). Again, teachers will have to guide students in this balance.

Lee (2002) promotes *instructional congruence*. Instructional congruence links the discipline of science with students' languages and cultural experiences. These connections are powerful and make science relevant. When these are woven together with language and literacy, English language skills and science knowledge are advanced (Lee, 2002).

Worldviews and school science. Worldviews influence students' experiences and engagement in science, and sometimes these worldviews are in contrast to the worldviews promoted in mainstream American school science curricula. For example, contemporary science education in the United States is deeply rooted in positivism, a philosophy that adheres to the premise that only things that can be observed can be truly known (Aikenhead & Ogawa, 2007; Stumpf, 1988). While this platform of observation and objectivity provides mutual starting points for discussing natural phenomena across cultures, positivism went further. It shunned theology and metaphysics, as well as the wisdom and values transmitted by them. In effect, it set up a false dichotomy. Those who embraced theology and metaphysics were deemed inferior by academia and were marginalized. There was no acknowledgement that people, regardless of culture and beliefs, employed science processes that enabled them to understand the world and to improve their lives (Aikenhead & Ogawa, 2007).

Positivism is perpetuated in most mainstream science classrooms through the curricula (Aikenhead & Ogawa, 2007). Teachers can build bridges to students who hold diverse worldviews and at the same time enrich the science classroom. Aikenhead and Ogawa (2007) suggest a modified version of positivism. Find commonality between students' worldviews and the objectives of the science standards. Add perspectives to what is known, and ask what values and knowledge are being transmitted through these perspectives. Aikenhead and Ogawa (2007) include a table of information borrowed from Stephens (2000) that explores areas of common ground between two world views (Appendix C).

The nature and language of science pose numerous challenges to students with diverse language backgrounds. With purposeful and astute planning, teachers can mitigate these challenges and accelerate the acquisition of science language and knowledge.

This second section of the literature review examined best practices in teaching academic language in science contexts to improve ELs' achievement in science. The third section will discuss how writing can enhance academic achievement and provide meaningful opportunities to develop writing skills.

The Value of Written Discourse

The ability to read is an essential skill in print-rich societies. Conversely, those who write can make their voice heard on numerous platforms. The ability to write well not only increases one's opportunities for self-expression, but it is often a prerequisite for higher levels of employment. A core expectation of science literacy is the ability to communicate clearly with others (Glynn & Muth, 1994).

Learning to Write

Society's value of writing is reflected in education standards across the disciplines. It is incumbent upon teachers to teach students how to write across content areas, including science.

The Common Core. The value and importance of written discourse is reflected in the Common Core State Standards for English Language Arts & Literacy (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). The writing benchmarks require students to be able to write in various genres and for different purposes. Two of these benchmarks, informative/explanatory and opinion (supported by strong reasoning) are purposes that can be applied in a science context.

Next Generation Science Standards. The Next Generation Science Standards detail practices that scientists employ and by extension should be incorporated into the science classroom (NGSS Lead States, 2013). These practices are often accomplished through writing in real-world science contexts to document and communicate. These practices include:

- asking questions and defining problems;
- developing and using models (labeling of diagrams);
- planning and carrying out investigations;
- analyzing and interpreting data;
- constructing explanations and designing solutions
- engaging in argument from evidence
- obtaining, evaluating and communicating information.

There are numerous ways writing can be meaningfully incorporated into the science classroom in preparation for careers in science fields. For specific ideas, see Appendix A.

Writing to Learn

In addition to the beneficial societal and personal outcomes of knowing how to write well, writing as a *process to learn* can influence learning, depending on context. Writing-to-learn is a strategy that fosters deep, reflective thinking of concepts learned as students write according to specific prompts. In a meta-analysis of writing-to-learn studies, researchers found that writing-to-learn can improve student learning to some degree as measured on conventional tests (Bangert-Drowns, Hurley & Wilkinson, 2004). The kind of writing that students do, the abilities that students bring to writing, and the frequency of writing tasks all influence achievement for the better. This being said, studies with a writing-to-learn treatment have shown that the improvement in scores compared to non-treatment scores were small. However, it is significant to note that in some studies that purposefully measured depth of knowledge gained through writing, students displayed a greater depth of knowledge on non-conventional assessments. Those who were treated with writing-to-learn tasks showed more sophistication in their knowledge (Bangert-Drowns et al., 2004). Writing-to-learn can also bring other benefits not measured on conventional tests including growth in metacognitive and thinking skills (Fry & Villagomez, 2012).

It is important to note that the participants in the studies mentioned above already knew how to write and may have used writing as part of their learning strategies, with or without treatment (Bangert-Drowns et al., 2004). These mature participants might have already learned how to learn through writing. If these students still showed positive effects from writing-to-learn instruction, there is reason to believe that writing-to-learn tasks would also benefit elementary students, especially ELs.

Writing is a 'minds-on' activity. Writing can help students achieve science literacy because it is a minds-on activity (Glynn & Muth, 1994). Glynn and Muth argue that teaching science facts is not enough to increase science achievement. Providing only hands-on activities is not sufficient either. Science experiments can too easily become superficial experiences if not tied to a reflective component. There must be minds-on tasks that help students articulate their knowledge (Glynn & Muth, 1994).

Writing is a minds-on activity because students wrestle with content and are forced to make sense of it. It causes newly acquired information, stored in short-term memory structures, to be reviewed and processed into long-term memory structures and become part of students' background knowledge. This process allows students to have the capacity to add new information to existing learning structures (Glynn & Muth, 1994).

Writing-to-learn reveals understanding. From a constructivist viewpoint, when students learn new information, they bring all of their experiences and facets of their identity into meaning-making. This includes what students believe, their values, their sociocultural background and prior knowledge (Glynn & Muth, 1994). No two students learn exactly the same content because they construct their knowledge differently. When students write, they articulate what they know, thereby giving teachers a window into their current understanding of scientific concepts (Huerta, Lara-Alecio, Tong & Irby, 2014). If the product is inaccurate, this too is helpful information for teachers in that it helps them know exactly what students are thinking.

Writing can bring numerous benefits to students in both learning to write and writing to learn. However, writing is the most challenging language domain for ELs. The literature identifies at least two reasons why this is so.

ELs and the Challenging Domain of Writing

It is widely known that writing is the most difficult language domain for ELs to acquire. The *English Learner Education in Minnesota* report shows that writing is the last achieved modality (Minnesota Department of Education, Division of Student Support, 2016, p. 25). Fewer than 5% of K-12 ELs in Minnesota scored at WIDA levels 5 and 6 (on a 1-6 scale with 6 considered grade level) according to the Fall 2016 report, compared with 43.4% in reading, 56.9% in listening, and 48.1% in speaking. In fact, no student scored at a level 6 in writing. There are several reasons why writing poses more challenges for ELs.

One-sided communication. One of the main reasons why writing tends to be difficult is because of the cognitive demands involved in producing language in written form. In oral language, meaning is negotiated between two or more participants and the language load is lessened. Clarification statements and questions between participants within a shared context support communication (Aguirre-Muñoz et al., 2009). Written discourse, on the other hand, is one-sided. Students write to an unknown audience that is not able to clarify meaning if the message is unclear. It is incumbent upon ELs to know what they want to say and to be able to clearly articulate their messages. In science, part of this skill is knowing how to use English effectively to communicate academic concepts in lieu of using informal language (Aguirre-Muñoz et al., 2009).

Synthesis of multiple skills. Many skills are needed to write effectively (Sousa, 2011). To write, students must employ knowledge of written mechanics (i.e. punctuation, syntax, alphabet); have enough knowledge of necessary vocabulary, grammar and composition; and draw upon their content knowledge to create a message. Good writing products demand a deep command of these skills because meaning cannot be negotiated.

Further exploring the interrelationship between *form* and *content* of writing in science is the research of Lee et al. (2011). *Form* in this study refers to how well writing is organized and communicates meaning. These researchers found that English proficiency is strongly correlated to scientific knowledge as demonstrated through writing. High-intermediate and advanced ELs and non-ELs were able to adequately articulate their understanding through writing and also showed achievement gains in science knowledge after intervention. This study's intervention was two-fold. Teachers received professional development prior to teaching science content. This training covered science concepts that were rooted in the curricula, how to use the materials, as well as how to incorporate English language and literacy development in a science context. ELs of mixed proficiencies were taught in English with vocabulary support, hands-on learning activities and visual aids.

While students of higher proficiencies showed achievement gains in both form and content, Lee et al. discovered that the intervention had a smaller effect in both areas of form and content for ELs of intermediate and lower proficiencies. The researchers further noted that the majority of students in their study were students from higher-proficiencies and the interventions were geared toward the higher levels. They speculated that more explicit instruction and the use of writing conferences might have led to stronger student achievement in the lower proficiency levels (Lee et al., 2011).

Although writing is uniquely challenging for ELs, it is nonetheless important. There are strategic ways that writing can be incorporated in a science context that would benefit both science objectives and writing skill development.

Best Practices in Incorporating Writing in a Science Context

There are several ideas and strategies to keep in mind while crafting instruction around writing in science. Some literature points to a general philosophy of instruction, while others describe specific components.

Cone of experience and inquiry-based learning. Since at least 1946, Edgar Dale's Cone of Experience (see Figure 1) continues to challenge methods of traditional education by providing a visual of how many senses are engaged in particular learning experiences and the levels of abstraction represented in them (Dale, 1946). Learning must be rooted in concrete experiences for students to make meaning. For example, *Direct, Purposeful Experiences*, the base of the cone, are real-life experiences in which

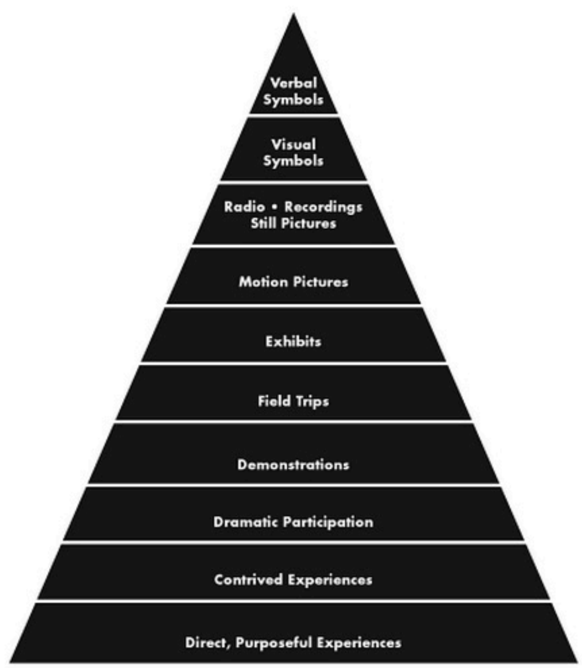

Figure 1. Edgar Dale's Cone of Experience (1946, p. 39) represents the range of educational experiences from the concrete to abstract. Activities at base of pyramid incorporate more senses than its apex.

participants are responsible for the outcome. An example of a real-life experience in science could be walking on a nature path and studying various animal tracks. These experiences involve most of the senses.

Dale describes how these experiences are necessary as they add concrete foundations to knowledge. Gradually, however, students learn to abstract these experiences. The most abstract experience of all, requiring the fewest senses, are verbal symbols represented at the tip of the cone. For example, the word *coyote track* does not look like a coyote track. The word only makes sense to the reader if the reader knows what a coyote is and that it can make a track of a particular shape.

All meaningful abstractions have a foundation of concrete experiences. In order for students to write abstractly about a subject, they must have some foundational concrete experience to draw from. This is one of the reasons why many researchers and educators promote inquiry-based, hands-on learning as an ideal pedagogy for ELs (Amaral et al., 2002; Huerta & Jackson, 2010; Klentschy, 2005; Lee, 2012; Moses et al., 2015).

Generally speaking, inquiry-based learning can be thought of as what teachers do to scaffold learning experiences in the form of investigations for questions that students have (Moses et al., 2015). Science is a natural setting for this. At its best, inquiry-based science learning inspires and engages students because it focuses on their interests and questions (van Uum, Verhoeff & Peeters, 2016). Sometimes, teachers must scaffold the inquiry process to support students who are younger or whose cultural backgrounds are not congruent with science inquiry. (Appendix B offers specific interventions teachers can incorporate.) The concrete experiences of lab work and experiments can lay a foundation allowing students to eventually abstract the knowledge gained, and ultimately to write about it.

Science notebooks. Having students use science notebooks is one way for students to organize their ideas around the inquiry process. As Klentschy (2005) summarizes, "A notebook is a central place where language, data, and experience work together to form meaning for the student" (p. 28). There, students can brainstorm ideas, hypothesize, record data, create, make connections to content, synthesize information and articulate their understanding of science concepts. Some researchers have used artifacts from science notebooks to analyze student knowledge and have developed evaluation tools helpful for assessing them (Huerta et al., 2014; Lee et al., 2011).

Klentschy (2005) outlines seven components of a science notebook that can be used by students to write through the inquiry process. These components also directly connect to NGSS. Summarized here, Klentschy found that having students write about these components led to higher-levels of thinking:

1. Question, problem, purpose (*What* and *how* questions are usually easier for elementary students to investigate, but there are also *why* questions that could be investigated.)
2. Prediction (Students give hypotheses, but also give reasons why they think their hypotheses are true.)
3. Planning (Describes the sequence, materials, and plan for data organization.)
4. Observations, Data, Claims and Evidence (This can include writing and drawings with labels.)

5. What have you learned? (Students analyze evidence and then interpret evidence in light of hypotheses. Students share their ideas and they learn from each other.)
6. Reflection (Students describe next steps and new questions.)

Klentschy attributes the increase of EL achievement in science, reading and writing to high-quality science instruction, which included the use of science notebooks.

Language functions of science. Teachers who aim to support students from diverse language backgrounds in writing should also expose the language functions of science. Science is not a list of facts. It is an interrelationship of concepts that form organized networks of information that connect in multiple ways (Glynn & Muth, 1994). Sometimes science knowledge is, by nature, enumerative. However, scientific facts can have a hierarchical relationship. Sometimes there are sequential or temporal relationships. Comparing and contrasting is often done to point out similarities and uniqueness, respectively. Scientific knowledge can be communicated by providing examples or by showing cause-and-effect relationships. New scientific facts can add or build on previous knowledge; sometimes it can contradict already established knowledge. Science can also be used to communicate solutions to problems (Glynn & Muth, 1994). Teaching students how to incorporate these relationships into their scientific writing is a powerful way for them to make connections, especially when the subject is relevant and has real-world application (Glynn & Muth, 1994).

Scaffolding writing. There are many ways that teachers can support students in scientific writing. One general way is for teachers to model thinking and writing (Zwiers, 2014). Modeling helps students conceptualize end products as well as show them *how* to get to the end product. Having students read science genres will also expose them to text structure, academic vocabulary and expression techniques (Glynn & Muth, 1994; Zwiers, 2014).

There are also specific tools teachers can use to support writing. After framing the writing prompt through real-world connections or hands-on experiences, teachers can utilize oral language to expand and crystalize students' thinking (Zwiers, 2014). Devising opportunities for students to talk to each other using academic language constructs can be helpful precursors to written discourse.

The use of graphic organizers can also be valuable tool for ELs (Zwiers, 2014). Graphic organizers collect and organize students' thinking. Graphic organizers can be completed by individual students or groups of students. It is important for teachers to model how to add information to graphic organizers as well as how graphic organizers can be used to structure writing products.

Word walls can be useful tools for students to reference during writing. Important content words that are introduced throughout lessons or from texts can be added to word walls. In addition, other words or phrases that help communicate academic content can also be recorded. Students can borrow these words to use in oral interactions and writing products (Zwiers, 2014).

A final best practice strategy, quality teacher feedback, will be discussed in the fourth section of this literature review. Quality teacher feedback can improve ELs' content knowledge, academic language and writing skills.

Quality Teacher Feedback

The studies referenced in the previous section have established that writing in science has been correlated with achievement, especially for students who have higher

English proficiencies (Lee et al., 2011; Ruiz-Primo et al., 2004). For students who have lower English proficiencies, the interventions used in these studies were not as beneficial. However, Lee et al. acknowledge that, in their study, instructional opportunities were missed. They recommend interventions that include quality teacher feedback to help these students.

The Value of Feedback from Teachers

One significant action that teachers can take to improve students' content knowledge and writing skills is to give quality feedback. Several researchers identified this as a worthwhile element to investigate in future studies (Lee et al., 2011; Ruiz-Primo et al., 2004). In forming this conclusion, one study observed that teachers did not give effective feedback or any feedback on products that students produced. Teachers either gave incorrect feedback, neglected to point out errors, or assigned grades without helpful comments about how content could be improved (Ruiz-Primo et al., 2004). Students require specific feedback in order to grow in their understanding and skills. Further, if teachers do not evaluate student work, especially entries in science notebooks, it is difficult to tailor future lessons to correct misconceptions or errors (Glynn & Muth, 1994).

Another study found that while writing in science notebooks correlated with science achievement, there were no improvements in writing skills over the course of a school year (Lee et al., 2011). However, the researchers also observed that teachers did not evaluate students' writing skills. Had students been given specific feedback on important skills and content, their writing products may have shown improvement (Lee et al., 2011).

There are several tools that teachers can use to provide quality feedback on content, academic language and writing skills. Two will be highlighted in this review: rubrics and writing conferences.

Rubrics

Several skills and areas of knowledge can be evaluated from the use of one multi-layered rubric. This type of rubric would be most useful to provide specific, quality feedback on science content, academic language use and writing skills (Haas, Hollimon & Lee, 2015; Huerta et al., 2014).

Assessing science knowledge. Generalized elements of accurate answers as well as common misconceptions can be thoughtfully organized in a rubric to represent depth of scientific knowledge. One resource to aid this process is AAAS Science Assessment (American Association for the Advancement of Science, 2017). Teacher manuals are also important resources.

In addition to content knowledge accuracy, students can be evaluated on their inquiry skills (Haas et al., 2015). Student can be evaluated on their ability to demonstrate adequate inquiry skills, such as making sound predictions, reporting solid evidence, and arguing using sound logic and evidence. This is a valuable category for some scientific writing; however, this may not apply to all genres or products that students write in a science context.

Assessing academic language. While students can be evaluated on the degree to which they are able to use Tier 2 and Tier 3 words accurately and frequently (Haas et al., 2015), Aguirre-Muñoz et al. (2009) argue that students in intermediate to advanced proficiencies must be given specific feedback on all aspects of academic language, not just vocabulary. Using a functional linguistic framework, teachers in this study were trained to provide feedback on students' use of transitions, point of view, verb phrases, noun phrases and theme/rheme. Using Christie and Derewianka's (2008) continuum of school discourse, a rubric—adjusted for age-appropriate characteristics, genre, and features of a given science writing product—can be used to assess academic language. Because academic language varies with different genres and content, different rubrics should be created to reflect these differences (Huerta et al., 2014).

Assessing writing skills. When designing the part of a rubric that assesses writing skills, teachers must consider age-appropriate writing expectations and language proficiency descriptors, such as the WIDA Can-do Descriptors (WIDA Consortium, 2015). Layering grade-level standards on English proficiency descriptors can inform appropriate rubric categories.

In the studies reviewed for this thesis (Huerta et al., 2014; Lee et al., 2011), various aspects of writing were combined into one score to represent writing skills. One score was used to evaluate conventions (spelling, capitalization, punctuation, subject/verb agreement, noun forms, correct use of plurals and comparisons), organization (indentation for paragraphs, development of ideas), and style/voice (sentence structures to communicate ideas, coherence). More detailed rubrics that separate these areas can provide quality, detailed feedback to students and to track their progress in given skills (Calkins, 2007). Students may excel in some aspects of writing and struggle with others. Detailed feedback is especially needed for students who have intermediate to advanced levels of English proficiency (Aguirre-Muñoz et al., 2009).

Rubrics are powerful tools; however, sometimes students do not know what to do with the information they are given. Sometimes their maturity levels or underdeveloped study skills prevent them from independently integrating the feedback they receive into their knowledge and skill structures. This is especially true of many elementary students. Writing conferences can meet this need and close the “feedback loop.”

Conferencing

Conferences are short meetings between teachers and individual students or small groups of students about an academic product that students created, usually writing products. In writing conferences, students are given the opportunity to review teacher feedback, clarify confusion, and practice skills. Conferencing can be used in other subjects as well. In a science context, student can receive feedback on writing assignments to further shape their understanding of the content and to encourage proper use of academic language. This is a very helpful model for ELs because student knowledge and writing are as unique as the students themselves (Aguirre-Muñoz et al., 2009).

A key component to this feedback process in writing conferences is what students do with the new information. Having students rewrite their ideas according to the feedback they receive adds extra opportunities to practice.

The Gap: Closing the “Feedback Loop”

Several research studies, described above, have acknowledged how writing can improve ELs’ achievement in science, especially of students with higher English proficiencies. However, there seems to be a gap in the research about how conferencing with a teacher and writing can be combined to refine students' understanding of science and writing skills, which is the focus of this study.

Research Questions

This study investigates how expository writing (explanatory genre) with quality feedback from teachers on content and academic language can positively influence achievement in these areas. Specifically, I am investigating the following questions.

1. How are 5th grade ELs' performances on an objective portion of a science quiz on erosion and deposition affected after discussing concepts with a teacher and writing about these concepts?
2. How are 5th grade ELs' written explanations of erosion and deposition and use of genre-appropriate language structures affected after conferencing with a teacher?

The information gleaned in this investigation offers practical strategies that mainstream and ESL teachers can implement to effectively support students with diverse language backgrounds in science.

Summary

In this chapter, a summary of four areas of the literature that pertain to the research question were presented. First, I described the achievement gap between ELs and their non-EL counterparts in science and showed how academic language is a significant factor in this gap. Second, I defined academic language and the unique difficulties that scientific academic language embodies. Best practices around academic language learning were presented. Third, the value and challenges of writing were described, along with ways to make writing in science meaningful and productive. Finally, rubrics and conferencing were offered as effective means to provide feedback to students. This section concluded with the identification of a possible gap in the literature. There seems to be a lack of research around how the pairing of conferencing (as a means to obtain quality feedback from teachers) and writing can consolidate ELs' science knowledge. Chapter Three describes the methodology used in the current study.

CHAPTER 3: Methodology

Introduction

In this capstone, I researched how basic writing routines that incorporate teacher feedback can lead to achievement gains in science for elementary ELs while simultaneously supporting their developing language skills. Specifically stated, I investigated answers for these two questions: How are 5th grade ELs' performances on an objective portion of a science quiz on erosion and deposition affected after conferencing with a teacher and writing about these concepts? How are 5th grade ELs' written explanations of erosion and deposition and use of genre-appropriate language structures affected after conferencing with a teacher?

Research has shown how science content, academic language and first-draft writing can coalesce into meaningful learning experiences. I wanted to investigate if more achievement gains could be realized after students received feedback from teachers in the context of a conference, and then wrote about the science concepts according to the feedback they received.

To investigate this hypothesis, I devised a research study involving elementary ELs and non-ELs from two schools that I worked in. In this chapter, I provide the methodology, rationale, general information about the participants and setting, detailed information about data collection techniques and the pilot study, a description of the scoring rubric, data collection, treatment procedures, data analysis tools, and a list of ethical considerations undertaken to protect the rights of the participants.

Methodology

This study falls under the category of qualitative research. Qualitative research employs descriptive data and does not rely heavily upon statistical methods of quantifying data (Mackey & Gass, 2016). While some objective data was collected through pre- and post-tests to determine the rudimentary efficacy of the treatment, greater insight was gleaned through analysis of descriptive notes taken during treatment. More specifically, this qualitative research study took the form of a case study in that it aimed to describe the various factors that may have influenced participants' performances before, during and after treatment (Mackey & Gass, 2016).

Participants

Participants were not chosen randomly. They were students at the two schools I taught in, and participants took part in the study in their respective buildings. Participants' proficiency levels ranged from intermediate to advanced, as well those who recently exited from the EL program.

There was a total of nine participants from 5^{th} Grade who participated in this study. Six of them were ELs who received treatment. Three participants were former ELs whose data was collected, but they did not receive the treatment. In addition, general statistical benchmark data from non-ELs' pre-test and post-instructional tests (administered after mainstream classroom instruction) was collected. Both the former ELs and non-ELs' pre-test and post-instructional test data were used as points of comparison.

Setting

The location of the school district's office is in a second-ring suburb of a large Midwestern city; however, the two schools are situated in a third-ring suburb. Although only two miles separate these schools, the populations of the two schools differ greatly and reflect the neighborhoods that feed them.

School 1. School 1 is more diverse, both socio-economically and racially. 20% of the school receives EL services. 52% of the students in this school qualify for the Free and Reduced-Price School Meals program. 42% of the students are White, 32% are Black, 14% are Hispanic, 2% are Asian, and 10% are two or more races.

School 2. In School 2, 5% of the school receives EL services. 26% of the students in this school qualify for the Free and Reduced-Price School Meals program. 65% of the students are White, 22% are Black, 5% are Hispanic, 5% are Asian, and 4% are biracial.

Participants

The 5th grade participants are listed under pseudonyms in Table 1.

Table 1

Participants' Pseudonyms, Home Languages, Genders and 2017 ACCESS Composite Scores

School 1 Participant	Home Language	Gender	2017 ACCESS Composite
Ayub	Somali	Male	4.3
Boran	Cambodian	Male	3.3
Caaliyah	Somali	Female	3.4
Daahir	Somali	Male	5.4 (Exited)
Eidi	Swahili	Female	4.4 (Exited)
School 2 Participant			
Faisah	Oromo	Female	2.6
Gil	Hebrew	Male	3.8
Hua	Hmong	Female	3.8
Ib	Hmong	Female	4.5 (Exited)

There were equal numbers of participants from each school who received EL services at the time of treatment. Their English proficiencies ranged from low-intermediate to advanced according to the 2017 ACCESS Composite Scores. Pre-test and Post-instruction test data was collected from participants who recently exited the EL program. They are identified in Table 1 as “Exited.” Six home languages were represented altogether.

Setting

The pre-test, mainstream curriculum instruction, and post-instruction test took place in mainstream classrooms to which participants were assigned. EL participants in both schools received the treatment in a pull-out setting. The pull-out setting was the typical service model for this age group at School 1. For School 2, this age group participated in a co-taught classroom for language arts instruction. The post-treatment test was administered in a pull-out setting.

Learning Objectives of Science Unit

The learning objectives that was selected to be the focus of this study came from the Minnesota Academic Standards in Science 5.3.1.2.2. This benchmark reads: “Explain how slow processes, such as water erosion, and rapid processes, such as landslides and volcanic eruptions, form features of the Earth's surface” (2009, p. 13).

My school district has chosen the FOSS Landforms curriculum (2005) to teach the process of erosion. Also covered in the FOSS curriculum is the concept of deposition. By particpating in the unit’s learning experiences, the teacher’s manual states that students should learn: “The wearing away of earth is erosion; the settling of eroded material is deposition” (Delta Education, 2005, p. 2). Erosion and deposition are complementary concepts, so I chose to include them both in this study. The real-world application of these processes presented in the FOSS curriclulum include the formation of canyons and deltas.

Data Collection

Data collection took two forms: field notes and tests. Field notes were observations taken by me during treatment sessions with ELs. The tests measured participants' understanding of science content as well as their writing. Tests were administered three times: pre-instruction (administered to ELs and non-ELs prior to mainstream instruction by the science teachers), post-instruction (administered to ELs and non-ELs after mainstream instruction by the science teachers), and post-treatment (administered only to ELs by me after conferencing with individual participants). All participants, ELs and non-ELs, completed these assessments as part of the normal assessment cycle of instruction. EL performance on the objective portion of the tests were compared to non-EL general statistical benchmarks as provided by the science teachers in an effort to increase the reliability of the study. All three tests administered (pre-instruction, post-instruction and post-treatment) were identical.

As the primary researcher, I spearheaded the design and development of the test. My experience teaching the 5th grade science curriculum guided this process. I chose concepts from a unit that is fundamentally important to the discipline and also difficult for most students to understand without explicit instruction. To aid in the development of the test, I consulted the teacher's manual and state standards to make sure the rigor and content of the test questions were aligned. Further, I referenced common misconceptions as identified by the AAAS (2017) to craft questions that probe student understanding. As a final step, I communicated with the mainstream teachers of the participants of this study. It was important that the content they planned to teach was aligned with and was reflected in the test questions.

Each of the three identical tests (pre-instruction, post-instruction, and post-treatment) had two parts. Part One was an objective measure of content knowledge of the predetermined lesson objectives. I designed this part of the test to be short and purposeful in that it informed me and the collaborating teachers of the participants' understanding of the lessons' objectives. Part Two was a constructed response and was used to evaluate how well participants were able to articulate content knowledge, use academic language, and write in English.

Part One of the Test

Part One consisted of six multiple choice and two short answer questions.

Multiple choice. Multiple choice questions quickly assess participants' knowledge and minimize the chances for participants to guess answers correctly. Experts suggest that multiple choice test items be stated as questions, not as fill-in-the-blank prompts. Further, experts recommend that questions should test participants' application of knowledge, not just basic recall (The University of Texas at Austin, Faculty Innovation Center, 2017). Figure 2 shows eight multiple choice questions developed for this study. Four questions are recall questions and four are application of knowledge questions. Every effort was taken to reduce the language load of each question and to remove language that may confuse or trick participants.

Landforms (Part 1)

Answer the questions below*. There is one answer for each question. Ask your teacher if you need help reading a question. Your teacher is not allowed to explain the meaning of words.*

1. What is a landform?
   a. a natural feature of the Earth
   b. a manmade feature of the Earth
   c. a tall feature of the Earth
   d. a person who forms land

2. Which one of these is an example of landform?
   a. hill
   b. house
   c. bird
   d. tree

3. Which one of these is **NOT** a landform?
   a. school
   b. ocean
   c. mountain
   d. river

4. What natural process makes canyons deeper?
   a. deposition
   b. erosion
   c. evaporation
   d. condensation

5. How long did it take for the Grand Canyon to form?
   a. It happened quickly (a few years)
   b. It took hundreds of years
   c. It took thousands of years
   d. It took millions of years.

6. What natural process forms deltas?
   a. deposition
   b. erosion
   c. evaporation
   d. condensation

Figure 2. Multiple-choice questions used for all three tests.

Short answer. There are only two short-answer questions. Short-answer questions are efficient ways to evaluate basic knowledge (The University of Texas at Austin, Faculty Innovation Center, 2017). By using short-answer questions, I hoped to see if participants were able to correctly name basic concepts using appropriate scientific vocabulary. A word bank was provided and included the two correct answers along with some distractors. Distractors were scientific words that participants had been exposed to in 4th Grade. See Figure 3.

Choose one word from the word bank to answer the question. *Write the word.*

Word Bank		
canyon condensation deposition	erosion evacuation evaporation	mountain repetition river

7. What is the process called when moving water, glaciers, or wind **pick up** earth materials?

    ____

8. What is the process called when water, glaciers, or wind **drop** earth materials in different locations?

    ____

Figure 3. Short-answer questions used for all three tests.

Part Two of the Test

Part Two had two sections. The first section set up the context for the second task, a constructed response.

Labeling features in photos or diagrams. This task, labeling features in photos or diagrams, was designed to assist participants in remembering terms in a context. These photos or diagrams were items that participants have had previous practice with. These items were not scored. They only serve to activate prior knowledge before participants attempt the constructed response. See Figure 4.

Landforms (Part 2)

11. ***Mark and label the five underlined landforms mentioned in the captions.*** *If you want, you can label more landforms that you see.*

This is a picture of parts of the Colorado Plateau, the Grand Canyon and the Colorado River as seen from an aircraft.

This picture shows the mouth of the Colorado River, the Colorado River delta and the Gulf of California.

Figure 4. Context questions used to activate prior knowledge. Left photo: Repreza, G. Grand Canyon. (n.d.). Licensed under Creative Commons Zero on Unsplash.com. Right photo: Earth Observatory, Johnson Space Center. (2004). *Colorado River Delta.* NASA images are in the public domain.

Constructed response. In the second section of Part Two, the final task of the test, participants were asked to complete a constructed response task around a prompt. The prompt referenced the context of the first section of Part Two. Constructed response questions are open-ended questions that allow participants to express their scientific knowledge through their current level of academic language. I used the explanatory genre of scientific writing.

A word bank with different noun and verb forms was provided. It has been my experience that students sometimes feel constrained by the form words take in word banks. Although they are told they can use different forms, many students use the form listed. Their sentence structures often sound awkward because they are trying to use the form of words that they are unaccustomed to using. By providing different forms of words, I hoped that participants were freed to express their knowledge in a way that was natural to them. See Figure 5.

10. ***How do canyons and deltas form?*** *Pretend that you are an earth scientist and the science museum asked you to write a paragraph for a display. Describe the natural processes that make canyons and deltas. You can borrow words from the word bank. You will **not** need all the words! Use extra paper if you need more space to write.*

Word Bank		
deposit, deposited, deposition **downstream** **earth materials**	**erode**, eroded, erosion **heavy**, heavier, heaviest **light**, lighter, lightest	**quick**, quicker, quickest, quickly **slow**, slower, slowest, slowly **upstream**

Figure 5. Constructed response question. Lined area was provided for writing.

Rubric. Constructed responses can be difficult to evaluate unless the teacher takes measures to ensure validity and reliability. Teachers have different ideas about what makes an answer well-written; even one teacher's evaluations can change throughout the day based on his or her state of mind. Carefully crafted rubrics are necessary to ensure validity and reliability in assessment. For this reason, I created a rubric that reflected appropriate grade-level content standards and language rigor.

The rubric evaluated participants in three areas: scientific accuracy, language structure for causal explanations, and writing mechanics. To increase the reliability and validity of the rubric, I asked an ESL colleague for feedback on it. See Figure 6.

Rubric* for 5th Grade Causal Explanation of Erosion and Deposition				
	1	**2**	**3**	**4**
Scientific Accuracy**	The explanation is incorrect; no understanding demonstrated	The explanation is partially correct or partially incomplete	The explanation is correct, includes: • how erosion happens • how deposition happens • mentions water as an actor • mentions long process, but does not quantify	The explanation is correct, AND elaborates on: • how differences in earth materials are deposited differently • quantifies length of process
Language Structure for Causal Explanations***	The explanation is incomplete, not coherent: • 1st person reference • not attitude neutral • does not use technical terms or use of terms not correct • ideas lack cohesion	The explanation is complete, but: • does not use technical terms appropriately, although intended meaning is discernable • all congruent phrases • mixed verb tenses, or verb tense not simple-present, or tense not appropriate for context • cohesion of ideas is mostly present	The explanation is complete, includes: • *erosion/ deposition* used appropriately (variations acceptable) • 3rd person • simple present tense, or tense appropriate for context • attitude neutral • cohesive ideas (e.g. references to cause/effect in theme position)	The explanation is complete, includes: • all appropriate technical terms • expanded nominal groups • clauses of time and reason • cohesive ideas with natural use of conjunctives
Writing Mechanics	Numerous errors in mechanics that significantly hinder/prevent understanding: • spelling • punctuation • grammar (word order, syntax)	Some errors in mechanics that may hinder/ prevent understanding in some places: • spelling • punctuation • grammar (word order, syntax)	Occasional errors in mechanics, but errors do not hinder or prevent understanding: • spelling • punctuation • grammar (word order, syntax)	Minimal errors in mechanics; grammar is like that of a native English writer
* Rubric acquired and adapted from Dr. Margarita Huerta (Huerta, Lara-Alecio, Tong, & Irby, 2014). ** Content descriptors acquired from FOSS Landforms teacher's manual (Delta Science, 2005) and AAAS Assessments (AAAS, 2017). *** Descriptors adapted from and Christie and Derewianka (2008) and Humphrey, Droga and Feez (2012).				

Figure 6. Rubric used to assess constructed responses.

Two Parts for Comparison Purposes

Parts One and Two of this test served unique purposes and are necessary to make comparisons between participants' receptive form of content knowledge (Part One), and the participants' ability to productively use academic language to explain what they know (Part Two). Part One of the study is important because ELs may find it easier to identify answers rather than to construct answers in writing. If, for example, participants were able to answer questions from Part One accurately, but were unable to complete the constructed response, one might be able to conclude that participants require more practice expressing the science concept in writing.

Pilot Study

I conducted two separate pilot studies—one for the test and the other for a treatment session. Because the test was newly crafted, I arranged to have same-grade students, a combination of ELs and non-ELs, from a similar setting who had recently completed the landform science unit take the test in order to identify potential problems with it. EL students in the pilot study did not receive direct EL support for the content of this science unit. This pilot identified three areas of the test that needed improvement.

Originally, the labeling of photos and diagrams was to be a scored segment of the test. However, having students label the photos and diagrams was problematic in that it was difficult to determine which labels went with which feature. Because the purpose of this segment was to provide a context for the constructed response, I decided not to score this task. This avoided potential confusion and inaccurate scoring.

I found a second issue with the test when I analyzed students' answers to specific questions in Part One. I noticed that students consistently answered one question wrong. I determined that the question was poorly constructed and changed it to be a fairer assessment of student understanding.

Students also had difficulties articulating answers for the constructed response question. All but two students left this answer blank. Only one of the two students who had attempted an answer had an answer that resembled an explanation. These answers (or lack thereof) might have been a function of students' uncertainty of how to explain concepts using the language of science. Displaying thinking stems was one way to support students as they crafted their responses (e.g. *Canyons are formed when…*). I advised teachers to use the thinking stem on the post-instruction test and I also used it in the post-treatment test.

In addition to the pilot test, I also I conducted a pilot treatment session with an EL from a different class who was not selected to participate in this study and who recently received instruction in the landforms science unit. My work with this student caused me to make two changes in the test. First, I streamlined treatment objectives. I simplified the test by eliminating one of the two science standards that I had targeted in the test. Covering both science standards in one 30-minute treatment was too ambitious. I also noticed that the distractor vocabulary in the word bank of Part Two overwhelmed this EL of low-intermediate proficiency. I decided to eliminate the distractors. My initial thought in including the distractors in Part Two was to prevent participants from using words in the word bank to infer correct answers in Part One. To avoid this potential issue, I had participants submit Part One of their test prior to taking Part Two. This way they would be unable to alter their answers on Part One.

The pilot treatment also helped me think through and prepare appropriate teaching materials. I prepared helpful visuals, identified a progression of concepts to cover, and designed activities to use to reach targeted objectives.

Procedures

Timing

The timing of this study coincided with timing of the mainstream classroom teachers' landform unit.

Sequence

Pre-instruction test. The pre-instruction test was administered near the launch of the unit. The data was collected and participants did not receive any feedback on their pre-test performance.

Instruction. After the pre-test, participants participated in classroom instruction around targeted objectives—the wearing away of earth is erosion; the settling of eroded material is deposition. These processes are seen in the development of landforms (i.e. canyons and deltas). Collaboration between the teachers and me prior to the unit's start ensured the content in this study was covered adequately.

The district-provided curriculum used in mainstream classrooms followed an inquiry-based model. The learning process outlined by the FOSS Landforms unit include a mixture of hands-on activities, whole-group discussion, as well as some teacher-led presentation of the material.

Post-instruction test. At the end of the instructional sequence, participants took the test again. They did not have access to, nor had they seen, their pre-test. The tests were scored using a key for Part One and a rubric for Part Two. Detailed notes were recorded for ELs' constructed responses—strengths and areas for improvement. My initial plan was to note one issue in each of the areas of scientific accuracy, language structure for causal explanations, and writing mechanics so as not to overwhelm participants. However, after seeing the actual writing samples and recognizing the large gaps of knowledge participants still had after mainstream instruction, I decided to prioritize feedback in scientific accuracy and use of academic vocabulary over other aspects of academic language and mechanics.

Treatment. Because most of the participants struggled with the understanding of science content, the treatment sessions consisted of one-to-one conferencing over science content that included mini-lessons and time to write a constructed response. Had particpants shown greater understanding of the science concepts, this treatment session would have taken the form of a classic writing workshop format where participants would have been given feedback on their previous writing and then asked to revise.

The number of mini-lessons that I presented to participants depended on their performance on the post-instruction test (See Appendix D). I met with individual ELs in a pull-out setting. Treatment sessions lasted from 25 minutes to one hour.

Throughout each writing conference, I took notes on what I presented, how participants responded, their successes and challenges, as well as other observations that were meaningful to the research questions. These notes were analyzed for patterns as I answered my research questions.

Post-treatment test. A third administration of the test (Part One as Part Two was part of the treatment) was given after the conference. Participants were allowed to reference the materials we used during the treatments' mini-lessons. Results from this third test was scored and analyzed in the same way as the first two.

Data Analysis

Participants' data were recorded in two spreadsheets, one for Part One and the other for Part Two. The left column listed participants' names so that the tests could be accurately recorded. When all the testing data had been entered, participants were assigned a pseudonym.

Data from Part One

The data from Part One was organized in a spreadsheet by question number and test. All question one answers from one participant were recorded side-by-side for easy comparison.

Scores from the ELs were compared with scores from former ELs who had taken the pre-test and the post-instruction test. In addition, the scores from ELs were compared with the mode, median, mean and range of non-ELs of the pre-test and post-instruction tests.

Data from Part Two

Data from the rubrics from Part Two was collected in a separate spreadsheet. Columns were grouped into triads, one column for each test. Each cluster of columns housed data from the three areas of the rubric: scientific accuracy, language structure for causal explanations, and writing mechanics. The scores for each rubric category were recorded in the cells. Post-treatment scores from ELs and post-instructional test scores of former ELs were compared.

To increase validity of the scoring of the writing samples, I had another ESL colleague score some writing samples using the same rubric. We discussed features of the writing in order to find consensus in scoring. This increased the validity of the scores so that accurate conclusions could be drawn from the data.

Notes Taken During Writing Conferences

While data from Part One and Part Two served as fundamental sources of data, field notes taken during the conferences added texture and insight to the conclusions formed. I took notes on treatment objectives that I identified for individual participants prior to treatment, the sequence of activities I employed during treatment to engage them in treatment objectives, and how they responded to and performed in the treatment activities. In addition, I took notes on how participants used the targeted vocabulary and how they articulated science concepts in both speaking and writing. The strategies and skills chosen for participants varied between each participant based on needs. Analyzing these differences and similarities and connecting the field notes with participants' tests added greater insight when answering the research questions.

Analyzing Patterns in the Data

Analyzing scores within and between each spreadsheet was very informative. Sub-sets of questions aided the analysis of the data. The question subsets are organized under their respective research question.

1. How are 5th grade ELs' performance on an objective portion of a science quiz on erosion and deposition affected after conferencing with a teacher and writing about these concepts?

- How well did participants perform from the pre-instruction test to the post-instruction test?
- How well did ELs' perform from the post-instruction to the post-treatment test?
- How do ELs' post-treatment scores compare to mainstream participants' post-instruction scores?

2. How are 5th grade ELs' written explanations of erosion and deposition and use of genre-appropriate language structures affected after conferencing with a teacher?
    - Did the clarity of ELs' content knowledge, as expressed in the constructed responses, improve after treatment?
    - Did ELs' use of genre-appropriate language, as expressed in the constructed responses, improve after treatment?
    - Did ELs' writing mechanics improve after treatment as displayed in the constructed responses?

A final question that probes answers for both research questions:

- Did all levels of ELs show the same degree of improvement?

By comparing the data using the questions above, I was able to see how ELs performed throughout the lesson sequence. I wanted to know if ELs' understanding of science content, use of academic language, and writing skills improved with treatment as compared to their non-EL peers.

Ethical Considerations for Studies Involving Human Subjects

Because this study involved human subjects, I carefully followed the research policies of Hamline University and my school district to protect the rights of the participants. The steps I took to ensure confidentiality included the following:

1. I gathered the appropriate authorization from parents/guardians and participants prior to the beginning of the study. These authorization forms were filed with my principals according to the policy set forth in my district.
2. Participants' names were used only for initial data collection purposes. However, once the data had been entered into the spreadsheets, participants' names were replaced by numbers in the spreadsheet.
3. Individual scores reported in this study were referred to by pseudonyms. Participants' names were not used in this thesis or any other related publication.
4. Participants and/or their parents/guardians were given the choice to decline participation at any time.

Conclusion

This chapter outlined in detail the features of this qualitative study, including participants, setting, procedures, materials, data collection methods, and ethical considerations. Chapter Four presents an analysis of the data gathered in the study.

CHAPTER 4: Results

This study took place over four months and there were two data collection cycles within these months. The majority of the ELs participated in this study in January and February. I coordinated data collection procedures with classroom teachers. Both teachers began and ended the landforms science unit within a week of each other. The pre-test was administered to all participants (EL and non-EL) near the beginning of the unit after they returned from winter break. The post-instruction test was administered by classroom teachers to all participants (EL and non-EL) after the unit's instruction was completed, around the second week of February. I corrected and analyzed benchmark data for the entire class to note general achievement patterns of EL and non-ELs. I then met with participants individually to administer the treatment plan during the last two weeks of February. Toward the end of each treatment session, participants completed the post-treatment quiz. I took notes during each treatment session and expanded on those observations after the session ended to add detail of the observations that I did not have time to write during the treatment sessions. I graded and analyzed the participants' responses and added their responses to two spreadsheets for easy comparison.

The second data collection cycle began in March and ended in the middle of May. Data was collected from one exited EL as her class received instruction on landforms as part of the science rotation between Grade 5 classrooms.

Through the collection of these data, I sought answers to these questions: How are 5th grade ELs' performances on an objective portion of a science quiz on erosion and deposition affected after discussing concepts with a teacher and writing about these concepts? How are 5th grade ELs' written explanations of erosion and deposition and use of genre-appropriate language structures affected after conferencing with a teacher?

Results of the Objective Portion of the Science Quizzes

The first research question asks how 5th grade ELs' performance on an objective portion of a science quiz on erosion and deposition are affected after discussing concepts with a teacher and writing about them. To investigate this question, I analyzed data to answer three sub-questions: How well did participants perform from the pre-instruction test to the post-instruction test? How well did ELs' perform from the post-instruction to the post-treatment test? How do ELs' post-treatment scores compare to mainstream participants' post-instruction scores? The data collected for each of these sub-questions are presented next. The data collected from individual participants can be traced analyzed using the first initial of their respective pseudonyms. Table 1 is repeated here for convenient reference.

Table 1

Participants' Pseudonyms, Home Languages, Genders and 2017 ACCESS Composite Scores

School 1 Participant	Home Language	Gender	2017 ACCESS Composite
Ayub	Somali	Male	4.3
Boran	Cambodian	Male	3.3
Caaliyah	Somali	Female	3.4
Daahir	Somali	Male	5.4 (Exited)
Eidi	Swahili	Female	4.4 (Exited)
School 2 Participant			
Faisah	Oromo	Female	2.6
Gil	Hebrew	Male	3.8
Hua	Hmong	Female	3.8
Ib	Hmong	Female	4.5 (Exited)

How well did participants perform from the pre-instruction test to the post-instruction test?

Comparing data from the pre-test and the post-instruction test quantifies how well EL and recently exited EL participants were able to acquire basic knowledge on erosion and deposition concepts in mainstream classrooms. Figures 7 and 8 show the results of the pre-test and post-instruction tests.

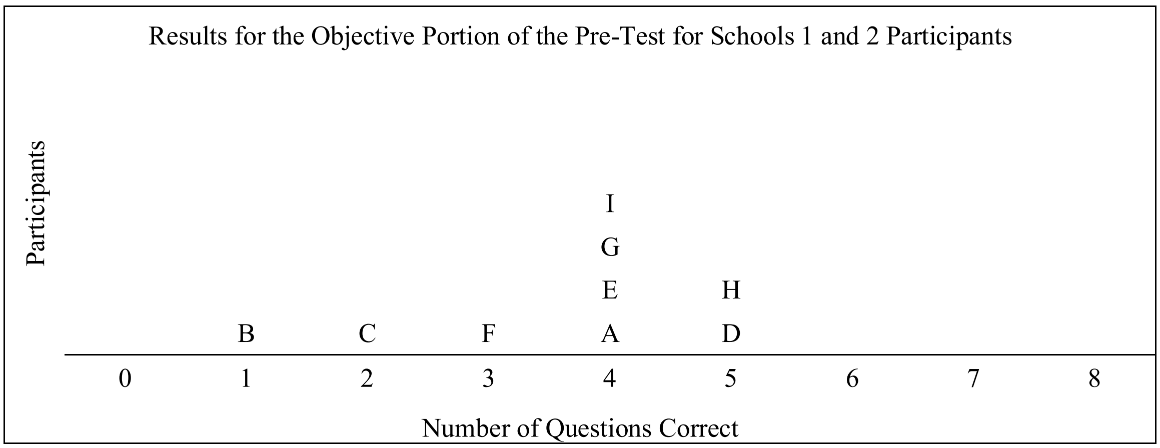

Figure 7. Line plot of EL and exited EL participants' results on the objective portion of the pre-test.

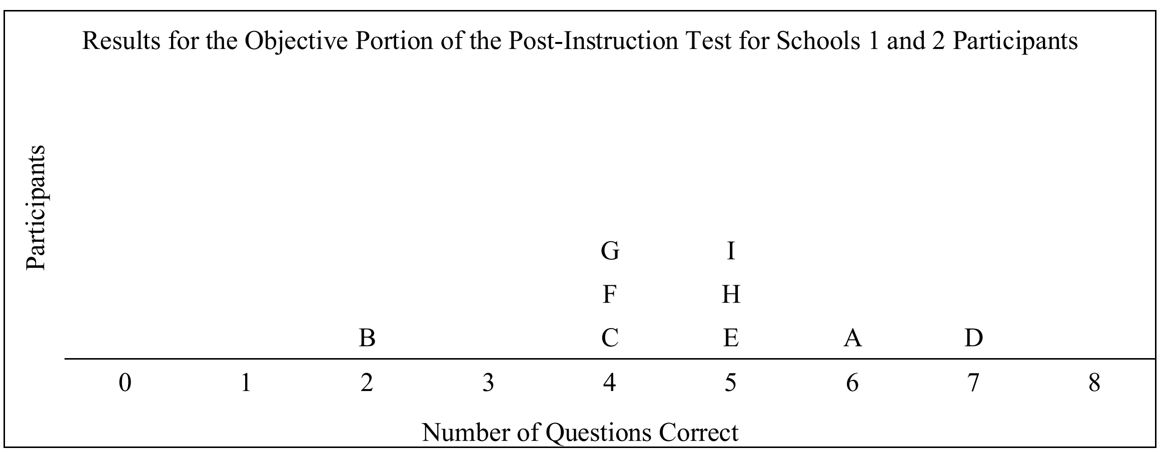

Figure 8. Line plot of EL and exited EL participants' results on the objective portion of the post-instruction test.

In comparing the line plots, participants gained one or two points on their previous scores after participating in mainstream classroom instruction. At School 1, all participants took part in the regular science content classes—no participants were pulled from science to receive Response to Intervention (RtI) or EL services. RtI is a service that provides struggling learners more opportunities to learn reading and/or math. In addition to EL services, one participant also received pull-out RtI reading services during science lessons. All participants, except for Daahir, failed to earn a passing score on the post-instruction test (passing is scoring 7/8 or 8/8). Daahir exited EL eight months prior to the treatment cycle. Eidi also exited the EL program at the same time, but she did not earn a passing score.

At School 2, two of the three ELs remained in the classroom for science instruction. Faizah was pulled for RtI services 15 minutes into science lessons throughout the unit. Faizah's score increased by one from the pre-test to the post-instruction test. The scores of the other two participants who remained in class, Gil and Hua, were unchanged after classroom instruction. Ib, an exited EL, was also pulled for RtI services 15 minutes into science and thus missed the bulk of science instruction. Her score increased by one from the pre-test to the post-instruction test.

How well did ELs perform from the post-instruction to the post-treatment test?

Comparing data from the post-instruction test and the post-treatment test evaluates how effective the treatment was in helping ELs learn about erosion and deposition. Figure 9 shows the results of the post-treatment test. Figure 8, the line plot of the post-instruction results, is repeated here for convenient comparison.

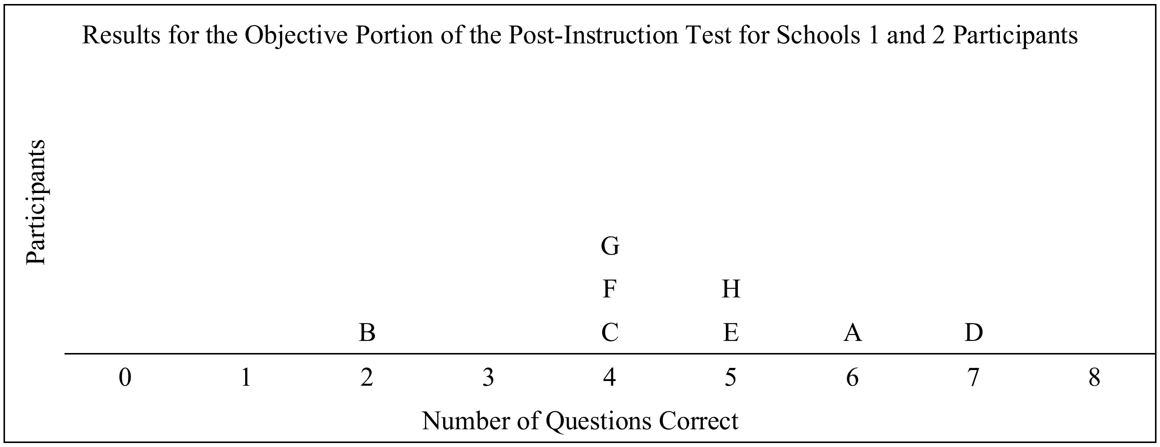

Figure 8. This line plot is repeated here so that results can be compared with the post-treatment test results.

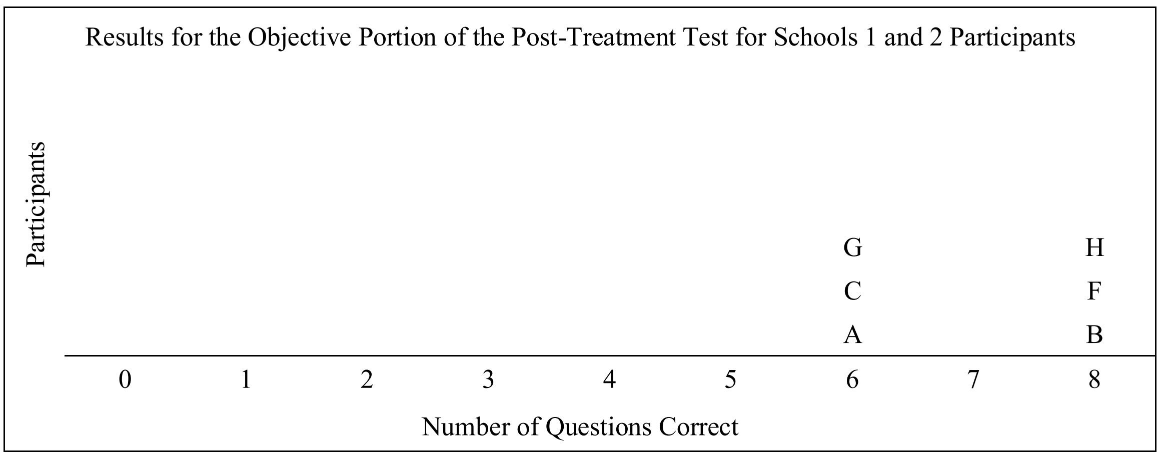

Figure 9. Line plot of EL participants' results on the objective portion of the post-treatment test. Exited ELs did not participate in the treatment sessions.

The majority of participants at Schools 1 and 2 improved on their scores after treatment, and where scores were not improved, the quality of the answers improved. The most significant improvement came from Boran. He scored six points above his post-instruction test to earn a perfect score on his post-treatment test.

Caaliyah increased her score by two points to receive a nearly passing score. I got the impression during the treatment session that learning is difficult for Caaliyah. Logical connections were missing in her descriptions and her comments seemed out of context and random. Even though she made personal connections between her life and the academic and scientific vocabulary as part of the treatment, she was unable to recall their meanings or apply understanding to those ideas several minutes later. However, by the end of our treatment session, she was able to correctly match erosion and deposition words to their definitions. The two questions she missed were the two application questions that asked participants to select the natural processes that form canyons and deltas. I felt the two-point increase was noteworthy because of the difficulties she had in remembering and expressing what she learned.

Ayub did not improve his overall score (6/8); however, the quality of his chosen answers improved. He applied his understanding correctly to the application questions, the most difficult type of question. The questions that he did not do well on were the two short answer questions. On the post-instruction test, he chose a non-related answer (condensation) to name the process of deposition. His post-treatment answers for the two short answer questions included the terms erosion and deposition, but the answers were switched. After he completed the test, I asked him to explain erosion and deposition again. He was able to use the correct term for the definition and used the same language I included in the question. I reviewed his answers with him and he was surprised at his mistake. He laughed and said that he had misread the questions. Had he not misread the questions, he would have earned full points.

At School 2, all participants improved their scores. Hua and Faizah increased their scores by three or four points, earning the maximum points possible. Gil improved his score by two points almost earning a passing score (6/8). The two questions he missed were the more difficult multiple-choice application questions. Surprisingly, he chose answers that were unrelated to the science unit (e.g. condensation, evaporation), even though he selected erosion and deposition for the short-answer questions. After this participant completed the quiz, I asked him to explain why he chose those answers. He said that he "had a feeling" that those were the correct answers. Although the answers for other questions on the three tests he took changed and improved throughout the three tests, his answers for these two questions remained consistent.

How do ELs' post-treatment scores compare to non-ELs' post-instruction scores?

The main purpose of this thesis is to investigate how the science achievement gap between ELs and their non-EL counterparts can be eliminated. Comparing ELs' post-treatment scores and non-ELs' post-instruction scores is necessary to establish whether the treatment's components were effective. Figures 10 and 11 present the raw post-instruction test data for Schools 1 and 2, respectively. Table 2 presents the benchmark data calculated from pre-test and post-instruction test data of non-ELs (including exited ELs). Table 3 contains the benchmark data for ELs of all three tests. The information from these figures and tables will be used to make general comparisons.

Results for the Objective Portion of the Post-Instruction Test for Non-ELs and Post-Treatment Test for Participants for School 1

Participants									
					x				
					x		C	x	
				x	x	x	A	x	B
				x	x	x	x	x	x
				x	x	x	x	x	x
	0	1	2	3	4	5	6	7	8

Number of Questions Correct

Figure 10. Line plot comparing non-EL post-instruction test scores and EL post-treatment test scores at School 1. Individual datum of non-ELs are represented with "x." EL participants are represented by the initial of their pseudonyms.

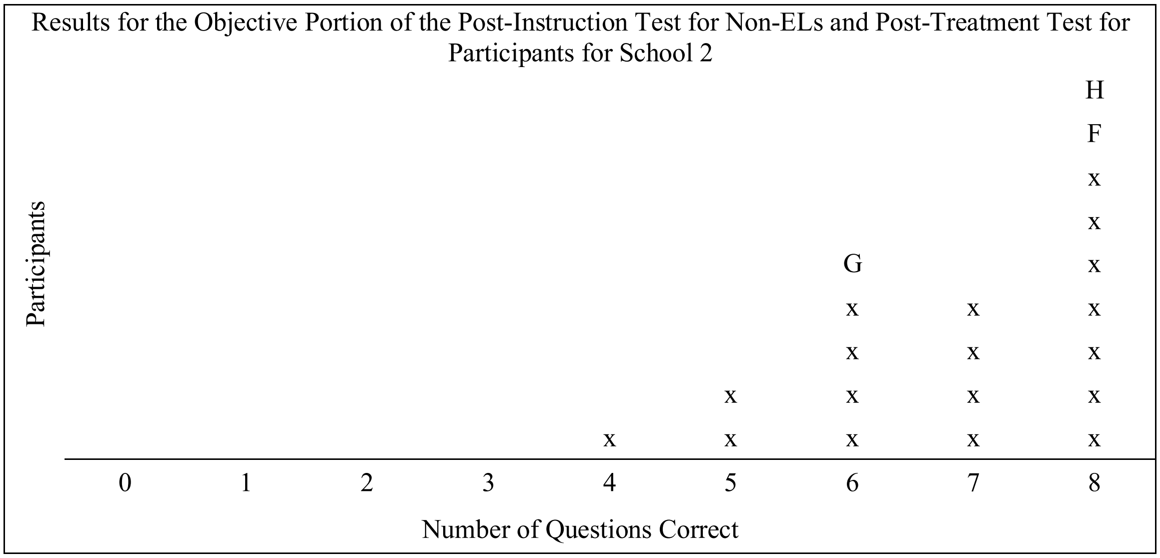

Figure 11. Line plot comparing non-EL post-instruction test scores and EL post-treatment test scores at School 2. Individual datum of non-ELs are represented with "x." EL participants are again represented by the initial of their pseudonyms.

Table 2

Benchmark Data of Non-ELs' and Exited ELs' Pre-Test and Post-Instruction Test

Pre-Test Benchmark Data	School 1	School 2
Mode	3	5
Median	4	5
Mean	3.8	5.1
Range	6	4
Post-Instruction Test Benchmark Data	School 1	School 2
Mode	4	8
Median	4.5	7
Mean	5.1	6.8
Range	5	4

Table 2 shows the effect of classroom instruction on non-ELs in Schools 1 and 2 as it relates to their understanding of erosion and deposition concepts. The performance of non-ELs varied greatly between the two schools. School 1 showed modest gains from pre-test to post-test. School 2 showed a greater increase in post-test scores.

While there were demographic differences between the 5^{th} graders of both schools—School 1 being significantly more diverse, both socio-economically and racially than School 2—there were also differences in instructional choices made by the teachers of those classrooms. School 1's teacher taught the science concepts as the district-provided curriculum recommended, employing hands-on experiments and whole-class discussion designed to foster student discovery and construction of knowledge. School 2's teacher crafted targeted mini-lectures around state science standards that related to erosion and deposition. Photos were used, and references were made to the hands-on experiments recommended by the district-provided curriculum, but no hands-on experiments were conducted by the students.

Table 3

Benchmark Data of EL Pre-Test, Post-Instruction Test and Post-Treatment Test

Pre-Test Benchmark Data	School 1	School 2
Mode	0	0
Median	2	4
Mean	2.3	4
Range	3	2
Post-Instruction Test Benchmark Data	School 1	School 2
Mode	0	4
Median	4	4
Mean	4	4.3
Range	2	1
Post-Treatment Test Benchmark Data	School 1	School 2
Mode	6	8
Median	6	8
Mean	6.7	7.3
Range	2	2

Table 3 shows the progression of ELs' scores from the pre-test, post-instruction test to the post-treatment test. The scores of six participants are represented in this table, three from School 1 and three from School 2. School 1's pre-test mean value was lower than School 2's pre-test scores by nearly two points. However, by the post-instruction test, the mean values were similar with a difference of three-tenths in favor of School 2. The mean values of ELs' post-treatment test scores from both schools show that ELs outperformed their non-EL counterparts when compared to the mean values of non-EL post-instruction test scores. School 1's ELs' outperformed non-ELs by 1.57 points; School 2's by 0.52.

School 1 and School 2's mean values of the ELs' post-treatment scores are also similar. In fact, one could argue that upon closer analysis they are exact. School 1's data includes Ayub's score—his post-treatment test was not an accurate representation of his knowledge. Had he not misread the last two questions, he would have earned the maximum score. The scores between the two schools would have been identical.

Did all levels of ELs show the same degree of improvement on the objective portion of the quiz?

Those who participated in the treatment were intermediate and advanced proficiency ELs; pre-test and post-instruction test data were collected for exited ELs. The intermediate and advanced proficiency ELs scored within the same range, 6/8 or 8/8. The four intermediate proficiency participants split their scores equally between 6/8 and 8/8. The two advanced proficiency participants had one of each score (one scored 8/8 and the other 6/8, although it is worth remembering that Ayub's score did not accurately reflect his knowledge).

Three exited ELs took the post-instruction test. Their scores were 8/8, 5/8 and 5/8. Their combined mean value was 6. Asad earned 8/8. Eidi (5/8) had difficulty with the application question about deposition and confused answers for the short answer portion of the quiz. However, the quality of her answers improved from pre-test to post-instruction test. Instead of selecting answers that had nothing to do with erosion and deposition, she chose terms that related to the content being tested. Ib (5/8) did well on the multiple-choice questions. She only erred on one question that probed knowledge about the length of time it took for canyons and deltas to form. However, she incorrectly answered the short-answer questions by selecting words that did not relate to the landforms unit.

Results of the Written Portion of the Science Quizzes

The second research question investigated how 5th grade ELs' written explanations of erosion and deposition and use of genre-appropriate language structures were affected after a conferencing with a teacher. To investigate this question, I compiled data for three sub-questions: Did the clarity of ELs' content knowledge, as expressed in the constructed responses, improve after treatment? Did ELs' use of genre-appropriate language, as expressed in the constructed responses, improve after treatment? Did ELs' writing mechanics improve after treatment as displayed in the constructed responses?

My initial plan was to tailor each treatment to address one issue in each of the areas of scientific accuracy, language structure for causal explanations, and writing mechanics so as not to overwhelm participants. However, after seeing the actual writing samples and recognizing the large gaps of knowledge participants still had after mainstream instruction, I decided to prioritize feedback in scientific accuracy and use of academic vocabulary over other aspects of academic language and mechanics. Academic language support was offered through the provision of sentence frames appropriate for causal explanations.

Before the data are presented, a caveat must be given about the data collected for this research question. As mentioned in Chapter 3, the purpose of the written portion of the science quiz changed from the post-instruction test to the post-treatment test. The post-instruction test showed how participants were able to independently articulate scientific concepts in written form. However, the writing that ELs completed during the treatment session was part of the treatment, and as such was laden with participant-teacher interaction. Caution must be used when comparing rubric scores of these tests. Coaching during the treatment should most definitely lead to higher scores and is therefore not an accurate representation of what participants might have written independently. While rubric scores were used to compare written samples, a greater reliance upon field notes was used here to interpret the impact of the participant-teacher conference.

Did the clarity of ELs' content knowledge, as expressed in the constructed responses, improve after treatment?

Across the board, ELs' content knowledge improved from the treatment as expressed in their constructed responses and as evaluated using the rubric (see Figure 6). Table 4 presents the scores for scientific accuracy reflected in participants' constructed responses.

Table 4

Scientific Accuracy of Participants' Constructed Responses

		Rubric score		
Participant	English Proficiency	Pre-Test	Post-Instruction	Post-Treatment
Ayub	advanced	3	2	4
Boran	intermediate	1	1	4
Caaliyah	intermediate	0	1	2-
Daahir	recently exited	1	1	N/A
Eidi	recently exited	1	1	N/A
Faizah	intermediate	1	1	3-
Gil	intermediate	1	1	4-
Hua	advanced	1	2	3
Ib	recently exited	1	1	N/A

Note. General rubric criteria are listed here. See Figure 6 for the detailed rubric used to evaluate constructed responses. Recently exited participants did not receive treatment.
0—no response
1—not scientifically accurate
2—limited scientific accuracy
3—expected scientific accuracy
4—exceeding expectations for scientific accuracy
- —intervention and support provided to achieve this score

In scoring constructed responses, I was specifically looking for three pieces of information to determine if writing samples met the basic criteria for scientific accuracy. A rubric score of 3 was assigned if the participant wrote a complete description of how canyons form through erosion, a separate and complete description of how deltas are formed through deposition, and a statement that reflected knowledge of the time it takes to form canyons and deltas. Information about how various earth materials are eroded and deposited differently were considered elaborations, earning a maximum score of 4.

All four intermediate-proficiency ELs had earned scores of 1 on their post-instruction constructed responses for scientific accuracy. Of the intermediate proficiency participants, Boran showed the most improvement. His post-instruction writing sample score was "1" because of an inaccurate description of deposition, although he was able to accurately write about erosion. During the instructional part of the treatment session, Boran needed reteaching on the basic concepts of what a landform is and what earth materials are. In our brief time together, he was able to quickly learn and articulate the information after each concept was introduced. Then, when it was time to start the writing part of the treatment, I only had to say the first sentence starter ("Canyons form when…") and he was able to independently and confidently write. He included basic ideas of erosion, deposition and time, as well as how earth materials are deposited differently based on their weight. He earned a score of "4."

Caaliyah struggled to remember the information presented to her earlier in the treatment session. While she was able to successfully speak about individual components after they were introduced to her, she had difficulties linking concepts together or even remembering what the concepts were minutes later. It was not surprising that she needed significant support during the written portion of the treatment. I verbally gave her the same sentence starter that I gave Boran and other participants. She had difficulty finishing the sentence. Without using words to finish the sentence, I used hand motions to pretend I was "picking up" something to see if that might help her remember the word erosion, or at least the words "pick up." I had her verbalize her thinking. Her ideas lacked clarity. I asked questions to help her think through her ideas and she was able to write down basic ideas. We went through a similar process as she prepared to write about deposition. Although her final writing product was of "3" quality, the amount of support I had to provide is better reflected with a score of "2." A "3-" reflects this qualification.

Faizah was able to write about erosion without assistance once she was given the sentence starter, but deposition was more difficult for her. Initially, she wanted to use "pick up" and "drop off" in the same sentence to describe how deltas form. I referenced the visuals used in the earlier part of the treatment session to show her again that erosion and deposition processes were related, but different. From this reminder, she was able to successfully write about deposition, earning her a final score of "3." A score of "3-" reflects the intervention that I made. It was interesting to me that during the instructional part of the treatment session, she was very interested in how different earth materials are deposited based on their weight. Even though she made several connections about these concepts during our discussion, none of it was included in her post-treatment writing sample. The only prompt I gave her was to ask, "What else do you know?"

Gil also needed sentence frames to get started. Articulating his understanding using erosion and deposition was difficult at first and he needed to verbalize his understanding again before he wrote. However, he found it easier to write about how long it took for canyons and deltas to form as well as how different kinds of earth materials are eroded and deposited differently. His writing sample was scored as a "4-" because of the initial assistance he needed to articulate erosion and deposition concepts.

The two advanced proficiency participants, Ayub and Hua, had slightly higher post-instruction scores for the scientific accuracy on the constructed responses. They both earned "2" because they correctly wrote about erosion; however, they did not explain deposition. After the instructional portion of the treatment, each participant was given the same sentence frame that was given to other participants. Both and Hua were able to successfully write about erosion and deposition without any coaching from me. Ayub's written explanation was clear and complete, earning him a "4." He needed no assistance or input from me. Hua required prompting to elaborate—"What else do you know?" When prompted, she continued writing, including information about how earth materials are deposited differently based on weight, but she did not include a time element. This earned her a score of "3."

Did ELs' use of genre-appropriate language, as expressed in the constructed responses, improve after treatment?

Most EL participants improved on their genre-appropriate language use on the constructed response from the post-instruction to the post-treatment tests. Table 5 presents these scores, as well as the pre-test scores.

Table 5

Genre-Appropriate Language in Participants' Constructed Responses

		Rubric score		
Participant	English Proficiency	Pre-Test	Post-Instruction	Post-Treatment
Ayub	advanced	3	3	2
Boran	intermediate	1	1	3
Caaliyah	intermediate	0	1	2-
Daahir	recently exited	2	3	N/A
Eidi	recently exited	1	2	N/A
Faizah	intermediate	1	1	2
Gil	intermediate	1	1	2
Hua	advanced	1	2	2
Ib	recently exited	1	1	N/A

Note. General rubric criteria are listed here. See Figure 6 for the detailed rubric used to evaluate constructed responses. Recently exited participants did not participate in the treatment.
0—no response
1—no genre-appropriate language observed
2—limited genre-appropriate language observed
3—expected genre-appropriate language observed
4—exceeding expectations for genre-appropriate language
- —intervention and support provided to achieve this score

The genre-appropriate language that I looked for in participants' writing included the use of the simple present tense, academic vocabulary (e.g. erosion, deposition, earth materials), and syntax appropriate for causal explanations (e.g. placement of cause/effect in theme position). While most participants did not earn a satisfactory score of "3," there were some modest improvements. It would appear that ELs of intermediate proficiency made the most gains on the post-treatment test, but it must be kept in mind that participants received coaching on their writing during the treatment.

Participants' post-instruction writing samples included use of the simple present tense and most writing samples were only one sentence long. Our conversations used the simple present when discussing processes of erosion and deposition and switched to simple past when discussing the application of these processes to the Grand Canyon and the Colorado River Delta. I did not prompt participants about which tense they should use when writing their explanations beyond the clue I gave them in the sentence starters, "Canyons form when…" and "Deltas form when…" Much of the focus during treatment was on using academic language in our speaking, with the intent that this language would translate into their writing. Inconsistent verb tense was an issue for many of these participants.

Ayub, advanced proficiency, was solid in his description, but did not always choose academic vocabulary. Instead of "deposition" he used "drops." In both his pre-test and post-instruction test, he used academic vocabulary appropriately to describe the processes of erosion and deposition. I am uncertain as to why he chose not to use the same vocabulary in the post-treatment writing sample. I did not explicitly tell Ayub to only use academic vocabulary, although he had the word bank from which to glean ideas. The word bank listed academic vocabulary. His verb tense was appropriate.

Boran, intermediate proficiency, used academic vocabulary without additional explanations or prompting. His sentences had the appropriate verb tense. All of his sentences were structurally congruent. His final score was a "3." This was up from a score of “1” on his previous constructed responses where he used no academic vocabulary and his explanations were disjointed phrases connected by colons.

Caaliyah, the participant of intermediate proficiency who struggled to remember concepts presented in the treatment, used academic vocabulary and correct verb tense in her final writing sample. However, she was unable to do this even partially independently. Her treatment score of “2-” reflects the difficulty she had recalling and using genre-appropriate language independently.

Faizah and Gil, both intermediate proficiency, used academic vocabulary accurately. Although they required some extra dialog about erosion and/or deposition during the writing process, our dialogue included the use of academic vocabulary (e.g. erosion and deposition) as well as simple phrases (e.g. pick up, drop off). Both of these participants chose to use the appropriate academic vocabulary without prompting. They both wrote significantly more than their earlier constructed responses. However, their verb tenses varied between simple past to simple present. Their genre-appropriate language scores increased from “1” to a “2.” This was a significant improvement from their post-instruction tests. Faizah used no technical terms in her earlier writing samples. Gil randomly listed words from the word bank on both the pre-test and the post-instruction test.

Hua, advanced proficiency, used academic vocabulary in her post-treatment writing sample. She used the simple present tense in her descriptions; however, there was one place where she used the future tense. When describing how earth materials are eroded differently based on weight, she used the future tense to describe what earth materials are eroded after the lighter materials are eroded first: “Then the river will pick up the heavier things like rocks and pebbles." I wondered why she used the future tense instead of a sequence word. Interestingly, in a language arts setting days after her treatment, I observed her using the future tense when listing a sequence of events of a novel. In addition to the simple past and future tenses, Hua's post-treatment writing sample also included the simple past. Hua post-instruction writing sample showed a large improvement in her use of academic language and in its completeness.

Did ELs' writing mechanics improve after treatment as displayed in the constructed responses?

When assessing writing mechanics, I looked for complete sentences, capitalizations, punctuation, spelling and subject-verb agreement. Table 6 shows the pre-test, post-instruction and post-treatment scores of the constructed responses.

Table 6

Writing Mechanics in Participants' Constructed Responses

		Rubric score		
Participant	English Proficiency	Pre-Test	Post-Instruction	Post-Treatment
Ayub	advanced	3	3	4
Boran	intermediate	1	1	3
Caaliyah	intermediate	0	2	3
Daahir	recently exited	2	2	N/A
Eidi	recently exited	2	2	N/A
Faizah	intermediate	3	3	2
Gil	intermediate	1	1	3
Hua	advanced	4	2	2
Ib	recently exited	1	1	N/A

Note. General rubric criteria are listed here. See Figure 6 for the detailed rubric used to evaluate constructed responses. Recently exited participants did not participate in the treatment.

0—no response
1—no use of proper mechanics
2—limited use of proper mechanics
3—expected use of proper mechanics
4—exceeding expectations for use of proper mechanics

Table 6 shows mixed results. Some participants' scores improved; some got worse. After participants finished writing, I reminded them to reread their work to check for capitals, punctuation and to make sure their writing made sense. Because much of our work in the treatment sessions was spent teaching, clarifying basic science concepts and encouraging the use of academic language, I chose not to directly coach participants on mechanics.

Ayub, advanced proficiency, wrote a well-written paragraph, earning himself a "4." He revised his own work without prompting and had no errors in mechanics.

Boran, intermediate proficiency, wrote a well-written basic paragraph with simple sentence structures. He had one error in verb form ("Canyons are form when…") and needed to be reminded to revise his work upon completion. These elements combined earned him a "3." This was a significant improvement on his post-instruction writing sample in which he wrote two short phrases connected by colons.

Although Caaliyah, intermediate proficiency, struggled with writing the content, she was able to write complete sentences with proper mechanics. Her ability to write complete sentences may have been influenced by the frequency of our interaction as she wrote. While I did not dictate words for her to write, I did have her verbalize what she was intending to write. I helped her clarify her ideas and then had her write. We did this for each part of the explanation (e.g. erosion, deposition, time it takes to form canyons and deltas). Her overall score was "3," but this score may not be an accurate representation of what she was able to produce independently. What she was able to produce independently is best seen in her post-instruction writing sample. The post-instruction writing sample had two sentences and she used capitals and punctuation. One sentence had better grammar than the other (omission of a preposition).

Faizah, intermediate proficiency, wrote significantly more during the treatment than on her previous writing samples. While her intended meaning could be deciphered, there were frequent mistakes in capitalization and subject-verb agreement. She earned a score of “2,” down from “3” in her post-instruction sample; although she wrote only two sentences in the post-instruction sample and both were sentences formed from the starters that were provided.

Gil, intermediate proficiency, wrote lists of words for his post-instruction writing sample. His post-treatment writing sample, however, was a “3.” Most of his sentences were complete and there was only one issue with subject-verb agreement. I noticed that one of his sentences was structurally incongruent, showing some sophistication of sentence structure.

Hua, advanced proficiency, wrote more in her post-treatment writing sample, and like Faizah, it contained more errors in mechanics. In her set of seven sentences, there were two fragments and some punctuation issues. Her post-instruction writing sample had three sentences. One of the sentences was a run-on sentence and another sentence contained one punctuation issue. It would appear that the frequency of errors did not improve from the post-instruction to the post-treatment. On her pre-test, she wrote one complete sentence with proper mechanics. The sentence she wrote began with the sentence starter provided to participants. The limited sample from the pre-test was scored as a “4.”

Did all levels of ELs show the same degree of improvement on the constructed response portion of the quiz?

All participants, intermediate and advanced proficiency, improved on the clarity of their scientific causal descriptions, although not all participants earned a score of “3” or higher. The one exception was Caaliyah who might have learning needs that compounded the complexities of learning.

All intermediate proficiency participants improved in their genre-appropriate language structures. They used more academic vocabulary, but some needed more instruction on which verb tense to use. Advanced proficiency participants did not seem to improve much in their use of academic language. Although Hua’s use of academic vocabulary improved, Ayub chose to use less. Hua’s writing showed a need for explicit instruction on verb tense for causal explanations.

Mechanics varied the most and seemed to have no pattern based on English proficiency. Participants from School 1 all saw an increase in scores for mechanics. Participants from School 2 only saw one increase from Gil (intermediate proficiency). Faizah and Hua (intermediate and advanced proficiency, respectively) both saw their mechanic scores decrease. It is important to note, however, that they wrote significantly more.

Exited ELs had difficulties explaining erosion and deposition on the post-instruction test. They received “1” for their explanations either because their explanations were incomplete (e.g. they only explained erosion, but not deposition), or because their descriptions were inaccurate. Asad was able to correctly and consistently use academic vocabulary in his explanation, while Eidi was able to do so 75% of the time. No specialized academic language appeared in Ib's writing samples, although she employed complex sentence structures and wrote in the simple-present tense. Asad, Eidi and Ib all scored "2" for mechanics. The common issues were capitalization and punctuation errors as well as subject-verb agreement. Eidi used inconsistent verb tenses.

Conclusion

This study sought and found answers to two research questions. The first was: How are 5^{th} grade ELs' performances on an objective portion of a science quiz on erosion and deposition affected after discussing concepts with a teacher and writing about these concepts? In short, meeting with participants to discuss and clarify concepts and having them write about their understanding improved their scores so much that they out-scored their non-EL counterparts.

The second research question was: How are 5th grade ELs' written explanations of erosion and deposition and use of genre-appropriate language structures affected after a conferencing with a teacher? Overall, ELs appeared to increase the accuracy of their explanations and their use of academic vocabulary. Participants struggled to consistently use the appropriate verb tense and to apply proper mechanics. However, no explicit instruction was provided on verb tense or mechanics as there were larger issues of content accuracy, clarity and use of academic vocabulary to address in the treatment sessions (as assessed from their post-instruction written samples). Exited ELs seems to struggle with similar writing errors that some intermediate and advanced proficiency participants struggled with.

In this chapter I presented the results of my data collection. In Chapter Five I will discuss my major findings, their implications, and suggestions for further research.

CHAPTER 5: Conclusions

For this study I investigated two research questions: How are 5th grade ELs' performances on an objective portion of a science quiz on erosion and deposition affected after discussing concepts with a teacher and writing about these concepts? How are 5th grade ELs' written explanations of erosion and deposition and use of genre-appropriate language structures affected after conferencing with a teacher? This chapter will discuss major findings gleaned from the data, limitations, implications for teachers, suggestions for further study and a reflection on the findings.

Major Findings

For the first research question that investigated the results of ELs' performances on the objective portion of a science quiz after meeting with a teacher to discuss and write about science concepts, I found that these interventions seemed to increase their understanding of the content. In fact, the treatment appeared to eliminate the predictability of EL science scores. NAEP and MCA data typically show that ELs trail non-ELs by a wider margin than other tested subjects (U.S. Department of Education, Institute of Education Sciences, National Center for Education Statistics, 2017; Minnesota Department of Education, Division of Student Support, 2016). The pre-test and post-instruction test data in my study mirrored what is happening nationally and at the state level—that the majority of ELs did not improve on their scores through typical mainstream instruction even though most non-ELs did show improvement. However, after treatment, ELs' scores matched and even surpassed non-ELs' scores. The components of the treatment were effective.

This might cause one to wonder about how the pedagogy choices used in the mainstream differed from the components of the treatment sessions. As was mentioned in Chapter Four, the teacher from School 1 taught the district-provided curriculum as was presented in the teacher's manual. This included a higher proportion of hands-on learning activities using FOSS stream tables paired with whole class discussions. The combination of hands-on activities and whole-class discussions were designed by the curriculum writers to allow students to construct their own knowledge using experiences from experiments. The teacher from School 2 designed lesson objectives and experiences around state science standards. There were no hands-on activities; however, she utilized videos of the same stream table experiments recommended by the district's science curriculum. These videos were supplemented by short lectures and whole-class discussions.

While the results of the non-ELs' post-instruction tests varied greatly between the buildings, the teaching approach seemed to be only a minor factor in EL post-instruction results. The EL participants scored one or two points higher on their post-instruction tests over their pre-tests at School 1 where more hands-on activities were utilized. Only one participant improved by one point at School 2. The scores of the other two participants remained unchanged. We know from Amaral et al. (2002) that hands-on learning is important for ELs, and this modest data set seems to favor that finding. However, the fact that only one participant, an exited EL, earned a passing score on the post-instruction test suggests that hands-on activities are not enough for ELs to fully understand this science content.

The treatment had four characteristics that benefited ELs. First, there was a clear presentation of basic science vocabulary and concepts. I specifically designed the instructional sequence of the treatment with the research of Kieffer et al. (2009) in mind. These researchers maintain that ELs require targeted, explicit and intensive instruction in each content domain to achieve academic success. In designing the treatment experience, I assumed nothing by beginning with the basic definition of what landforms are. While most participants demonstrated adequate knowledge of this definition, two did not. The fact that two ELs did not understand the most basic concept of the science unit was surprising to me especially because they had fully participated in the science unit and were not pulled for services. These ELs needed more explicit instruction.

Further, science knowledge is hierarchical (Christie & Derewianka, 2008; Christie & Martin, 2007; Halliday & Martin, 2004). During the treatment sessions, I made sure that ELs had a firm grasp of fundamental concepts and vocabulary before introducing more advanced concepts that required this background knowledge. The purposeful layering of science vocabulary and concepts appeared to be effective. The high scores that ELs earned on the post-treatment test and their ability to use this language in speaking and writing underscored what the literature shows. Building a strong foundation of content vocabulary and concepts so that ELs can access hierarchical knowledge structures of science is a powerful tool in helping ELs achieve in science.

Another feature of the treatment that was important was how speaking was incorporated into the lesson sequence of the treatment. After each new term or concept was presented, participants were asked to retell what was presented. In the mainstream, speaking is often used to engage students in the learning process or to help students commit information to memory. While these aims are important for ELs too, the research shows that speaking allows students to communicate ideas and negotiate meaning along the way (Zwiers, 2014). Speaking benefits ELs in that it forces them to articulate their understanding of the concepts and to practice academic language in a way that is less intimidating than writing. Meeting with participants in a conference setting for the treatment allowed participants to practice their knowledge in a supportive environment. Many of the 5th grade ELs in this study are passive learners. They listen to teachers, pay attention during whole-group discussions, and join with classmates in groupwork; however, they generally lack the confidence to share their academic knowledge or use academic language in front of others without the assurance that their ideas are acceptable. In groupwork, they often follow the lead of other students and add very little in the way of academic input. If students do not speak, then they do not receive the feedback they need to refine their understanding.

Feedback is vital, and it is the third component of what made the treatment successful. Several researchers (Lee et al., 2011; Ruiz-Primo et al., 2004; Glynn & Muth, 1994) highlight the importance of quality feedback. I made feedback a prominent feature in the treatment that participants received, and it was offered frequently. After participants verbalized their understanding of each science term and concepts, I gave them feedback. I acknowledged correct answers, suggested alternate vocabulary, added clauses to refine their explanations, or corrected misconceptions. If refinements or corrections were given, I had participants try again to verbalize their understanding. We continued this process until they adequately articulated the targeted vocabulary and concepts. I found a direct correlation between what participants were able to communicate and what they understood. If they were unable to articulate ideas given the language support and visuals they had access to, then I found that they did not adequately own the knowledge enough to be successful on the quiz.

The placement of feedback in the instructional-assessment cycle is also important. During treatment, participants were given feedback and opportunities to practice their knowledge before completing the summative assessment (the post-treatment test). It has been my observation in mainstream settings that providing feedback prior to administering summative assessments more frequently happens in reading and math. Because the time for teaching science is limited, providing feedback and offering opportunities to practice and refine scientific knowledge is not prioritized and is frequently skipped. Any feedback that students receive comes from graded assessments. Many 5th grade students have yet to develop the student skills needed to investigate why their answers are incorrect. Well-timed teacher feedback and practice before summative assessments is necessary to increase achievement in science.

The fourth and final component that made this treatment successful was the incorporation of writing. The literature (Huerta et al., 2014; Glynn & Muth, 1994) identifies writing as an important tool in the learning process because it forces students to articulate what they know. Once the participants verbalized their understanding and received feedback from me on the terms and concepts related to erosion and deposition, participants were asked to write a causal explanation of how canyons and deltas form. This culminating exercise helped ELs consolidate their understanding. The isolated speaking tasks that participants engaged in throughout the treatment scaffolded their understanding of the basic terms and concepts. The writing exercise required participants to think through how the science concepts interrelate and connect with each other.

The kind of writing that participants engaged in during the treatment session was different from teacher-led writing. Sometimes in the mainstream classroom and in EL pull-out settings, teachers might lead students in writing notes, definitions for terms, and answers to questions. Modeling is important and is necessary, especially for students who rely on examples to understand the structure and goal of an assignment or graphic organizer. I would posit, however, that copying words is not the same kind of writing that will consolidate student knowledge. If students rely on models to copy information, it means that they do not own the information. The kind of writing that will most likely benefit ELs is the kind that affords them the opportunity to use the language they have acquired through quality input, speaking and feedback, and to compose products that show holistic understanding of concepts.

Constructed responses, such as the one used in this study, are important because ELs must integrate their knowledge and commit their understanding to paper. In the treatment sessions, if participants were unsure of what to write, their confusion was either voiced in their questions or in their verbal attempts to explain as they wrote. The coaching I provided for most participants came in the form of questions, vocabulary choices, and in sentence frames. For Caaliyah, I went a step further and used hand motions to support her memory. However, I refrained from dictating or modeling what participants should write because it was important for them to apply the appropriate vocabulary and in the process construct their own knowledge as they think through the ideas. This writing exercise caused them to think deeply about the concepts and helped them make other connections. Their newly refined knowledge-structures were represented in the clarity and completeness of their written explanations and ultimately influenced their answers on the objective portion of the final science quiz.

The data collected in this study suggest that a clear presentation of science terms and concepts, opportunities for speaking, feedback with practice and writing were useful tools in eliminating the science achievement gap between intermediate and advanced ELs and non-ELs on the objective portion of the science quiz. The EL scores on the post-treatment test were not distinguishable from the post-instructional test of the non-ELs. It stands to reason that if generalized to other science content, ELs would likely benefit from similar opportunities to receive quality input, speak, receive feedback and to write. In addition, exited ELs who struggled with the content could have benefited from the treatment as well as some non-ELs.

The discussion of the second research question that investigated the clarity of explanations and use of genre-appropriate language structures in writing builds on what the first research question determined. The four components of the treatment—quality input, opportunities for speaking, feedback with practice, and writing—supported participants' developing writing skills. As alluded to earlier, the treatment components seemed to help participants own enough of the scientific knowledge and language to increase the clarity of their explanations.

Guided writing experiences, such as what took place during the treatments, helped participants elaborate. It has been my experience that many 5th graders are still internalizing their sense of what a thorough answer is and how to evaluate written answers in terms of completeness. Independent writing samples, even if specific requirements are detailed beforehand, are often incomplete and lack cohesion. Guided writing exercises, whether in whole group or in a small group setting, usually result in greater elaboration. In this treatment, simply asking participants to “tell more” or asking, “What else do you know?” was enough to spur them on. Asking participants to elaborate provided additional opportunities for them to consolidate their knowledge of scientific concepts while also reinforcing the criteria for quality answers. Calkins (2007) advocates for guided writing experiences, and I found this tool to be useful.

Further, core features of the treatment supported participants’ acquisition of academic language. Defining terms is always a necessary element of academic language acquisition, but they cannot stand alone. In the treatment, ELs benefited from the process of speaking and receiving feedback on their understanding and use of the academic language. For example, when I asked Boran to explain erosion using the before-and-after photos of land that was eroded by a river, he redundantly used “erode” and “pick up” in the same sentence (i.e. “The river eroded and picked up and…”). I reiterated that these two terms mean the same thing and modeled sentences using only one of the terms. From then on, he was successfully able to use erode in sentences when speaking and in the writing task. This was one example of a larger trend I saw with all participants. If participants were unable to articulate their understanding clearly using academic language, it was usually because they did not understand the concept, or they felt insecure explaining it. If they were able to successfully describe the concept in speech, there was a greater probability that this knowledge would be reflected in their writing.

One genre-appropriate language structure—verb tense—was not specifically addressed in the treatment. It was modeled in the treatment, but participants were not given reminders about what verb tense to use in writing. It was interesting to see the variety of verb tenses that participants of all proficiencies chose to use. Even advanced participants struggled with verb tense choice. Had I had the opportunity to conduct a follow-up session, I would have designed a mini-lesson on genre-appropriate verb tense usage and would have had participants revise their writing. I would have also included editing routines to improve mechanics. Because this treatment prioritized science content knowledge, the content of the writing and the academic vocabulary used to express those ideas were given first priority. Had participants come with a greater knowledge of the content, I would have spent the treatment refining verb tense and mechanics.

It might be tempting to downplay the positive outcomes of this investigation because meeting one-on-one with participants seems like a no-fail venture. I would argue that the increase in achievement of ELs was not solely due to group size. Incorporating opportunities for participants to speak and write gave me opportunities to provide targeted feedback. Had I met one-on-one with participants to present the material, but not offered opportunities to speak, write, and give feedback, I believe that participants' scores would not have seen the same increases. I confidently offer this prediction because of what I observed during the treatment sessions. When participants were asked to verbally share their knowledge, their explanations were incomplete or inaccurate. I needed to give them feedback to correct, clarify and refine their understanding.

The benefits of receiving feedback on speaking and writing activities were clearly evident to me, the researcher and observer. They were also evident to at least one participant. At the end of her treatment session, Hua and I had a spontaneous and brief conversation that I did not plan to have as part of the treatment. The conversation began with Hua thanking me. Her expression of gratitude surprised me because she did not just say a polite "thank you" before leaving for her classroom as some of my students do. She specifically thanked me for helping her understand the science concepts. Her comment led me to probe her metacognition and I asked her why she felt that our time together was helpful. She said that it was helpful to talk together and to write about the science concepts. With this comment, I believe she recognized three of the four components of the treatment—speaking, writing and feedback (if "together" can be interpreted as feedback). I was impressed with the fact that she recognized what strategies she benefited from, and I felt validated that the components of the treatment were effective.

Limitations

Overall, the study went as I expected, although there were a few minor adjustments I had to make along the way. I thought I had coordinated the timing of the pretest administration with the teacher from School 2, only to find that she had already taught two lessons of the unit when I delivered the pretest to her. The two lessons she had already covered were about what is/is not a landform. I had her administer the pre-test anyway. At first, I feared that the pre-test results would be skewed. But when I compared the pre-test results to School 1's pre-test results, I surprisingly found that the scores were comparable. Nearly all of the ELs and non-ELs got the first three questions right regardless of what school they attended and when they took the pre-test. The fact that both schools had comparable scores made me conclude that these 5th grade students either came with sufficient background knowledge about what landforms are and are not, or they were able to employ enough logic to deduce the correct answers to these questions. I concluded from this comparison that the late administration of the pre-test at School 2 did not appear to affect the conclusions I was able to draw.

Another surprise came when I had analyzed participants' constructed responses on the post-instruction test. I did not anticipate that the written products would lack so much content and that I would have to reteach much of the content. While standardized test results of ELs might have caused me to anticipate this discrepancy, I had mistakenly thought that a simpler assessment, such as the one I created, would have provided greater substance to work with. I thought that this would be especially true because the quiz was directly connected to content that students recently finished learning about. This discrepancy in achievement underscored my urgency to determine effective strategies to bridge students' knowledge to content standards.

My initial plan at the beginning of this study was to work with participants in small groups, as might a mainstream classroom teacher. As I prepared to conduct the treatment sessions, I felt it would be more insightful to analyze the learning patterns of individual participants. Small groups of students can bring complicated dynamics that are hard to document and identify in a study. While I felt good about the quality of the analysis of participants' responses and the conclusions drawn based on substantive field notes and data samples, I have to acknowledge that one-on-one instruction is not practical or sustainable in the typical mainstream classroom model. In designing one-on-one treatment, it was not my intention for teachers to duplicate the exact treatment parameters for mainstream or EL settings. The aim of this study was to determine if writing routines could help ELs consolidate their scientific knowledge and improve their writing. Now that the data suggests they can, the next step is to scale these experiences to other settings.

One last limitation to recognize is that I had hoped to include students who were at or near beginning English proficiencies. I wanted to analyze their experiences and track their progress through the same treatment cycle to determine the benefits that might come from the speaking, writing and feedback components. Unfortunately, the beginning English proficiency students were students of other 5th grade classes who had already participated in the landforms unit by the time I was ready to gather data. Relevant data points for comparison could not be collected.

Implications

I have identified three main categories for implications from the findings of this study—immediate, short-range and long-range. The most fundamental and immediate challenge is to our beliefs about what intermediate and advanced proficiency ELs are capable of accomplishing in science given the proper support. In a side conversation I had with a teacher not connected with this study, I was asked about my findings. I shared a brief overview of the study and how the scores of the ELs I worked with matched or surpassed mainstream students' scores, and I was in the process of analyzing why the treatments sessions were effective. The teacher commented that any child would perform well when working one-on-one with a teacher because they are less distracted by what happens in the classroom. I pointed out that the majority of non-ELs from this teacher's school improved with instruction. ELs' scores, by and large, did not improve and were far from passing. At this point, our conversation was cut short because students were returning to class. Had I had more time, I would have liked to respectfully challenge this teacher's expectations and assumptions by asserting that ELs *can* reach these higher scores with the proper instructional supports. It is possible that intermediate and advanced EL science scores can be indistinguishable from their non-EL counterparts. We need to figure out how to give the proper support in a mainstream setting.

A mid-range implication is to consider how EL teachers might reproduce the same or similar instructional components to teach language objectives through science content. This can be done for an EL setting or in support of mainstream instruction. Once language and science objectives are identified for various grade levels, science concepts can be deconstructed. Understanding can be scaffolded with clear terms, examples, and pictures with real-world applications. Students could be provided with feedback as they articulate and write about content all the while applying academic language. These elements have the likelihood of simultaneously propelling ELs' understanding of language and science further.

A long-range implication is to consider how mainstream teachers might use similar speaking and writing components with feedback in the mainstream classroom. As I interface with teachers in my elementary buildings, I see their efforts to engage students in lessons using conversation. These opportunities are important; however, the most benefit for ELs is to provide feedback on the language they are using so that they can refine their understanding. Many ELs passively participate in whole group activities and student-led small group activities. Discovering ways to actively encourage participation in any discussion or writing activity, whole or small-group, must be a priority. Finding ways to give feedback is a necessary, not optional.

Meeting with students in small groups is one way to facilitate participation and feedback. Many teachers already meet with students in guided reading groups during the literacy block and have established writing routines. With purposeful planning, teachers can integrate science with the literacy block. Teachers can meet with small groups to discuss science texts and to provide feedback on their written work. Aligning several instructional goals across the disciplines can accelerate the learning of ELs and non-ELs alike.

Further Research

The results of this study raise several questions worthy of further investigation. In this study, ELs seemed to benefit from the content being presented to them one-on-one. This setting allowed for more immediate and frequent feedback. At what number do small groups lose their benefits? Does this depend on the proficiency of the EL, the nature of the content being taught, the pedagogy utilized, or the intrinsic characteristics of the learner (e.g. motivation, affective filter)? How can we identify and maximize the variables to equitably support ELs achievement in science?

Another research topic that would be interesting to investigate is how participants' writing scores might have changed had a follow-up treatment session been conducted to address writing form. If mini-lessons were presented on verb tense and mechanics, would participants have generalized this knowledge and successfully revised their writing samples from the post-treatment test?

These next and final questions are rooted in leadership as much as in scholarship. How can EL and mainstream teachers align their content and classroom practices to include opportunities for more discussion, feedback and writing in science as well as other content areas? How can this conversation and collaboration be facilitated across a school district? Are there proven models that streamline the planning and record-keeping processes? What indicators would validate the investment of time and resources that such a vision would require?

This study offers some promising insight as to how ELs can be supported to achieve in science. It also reveals many more questions that must be answered to make achievement in science a consistent reality for all ELs.

Reflection

This capstone research experience has made me a better educator in that it has honed my pedagogy. Reviewing the literature exposed me to a range of research that was connected directly to my chosen topic and tangentially related. The range and volume of research challenged me to critically analyze how assertions might lead to potential answers to my research questions. Appraising the research through the lens of my classroom and EL teaching experiences further served to clarify my beliefs about what was possible, viable, and necessary when teaching science content to ELs. Because the treatment components—explicit teaching of vocabulary, opportunities for speaking, writing, and feedback—brought success to my ELs, they are now consciously included in lessons I create. They are not just tools in my educator toolkit, and no longer actions that stem from teacher intuition. They are components that I purposefully look for when referencing district-provided curriculum, consciously add if they are absent, and systematically incorporate across content areas.

This capstone experience has also fueled my vision for EL achievement in science. My next challenge is to partner with mainstream teachers to support them as they teach ELs. Showing proof that intermediate and advanced ELs can achieve in science might open conversations about what instructional elements could support ELs in mainstream instruction. Sharing my findings can inform classroom teachers of the necessary components for EL success. I envision partnering with mainstream teachers to figure out how these treatment components can be effectively incorporated in mainstream classrooms.

In the process of the completing this capstone, I have often reflected on my experience teaching 5th grade mainstream science. My former EL that was so enthralled with the 50 bugs yet struggled to learn the content was not far from my mind as I conducted this study. I wonder how my ELs' experiences in my classroom would have been impacted had I been armed with the knowledge gained from this capstone research experience.

Conclusion

This case study investigated how writing routines can be leveraged to consolidate scientific knowledge of ELs and advance their acquisition of academic language. Writing routines, which should include opportunities for quality input, speaking and ways to receive feedback, are effective ways to support ELs in their learning of content knowledge and their acquisition of academic language. These components were effective tools to eliminate the science achievement gap between intermediate and advanced proficiency ELs and their non-EL counterparts in this study. More work must be done to identify ways that these components can be scaled to larger groups of ELs and be utilized in mainstream settings.

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Appendix A

Strategies to Support Literacy and Language Acquisition in Science

Lee and Buxton (2013) reviewed the literature and found five domains that teachers can apply specific strategies to support literacy and language acquisition through science instruction. These include:

1. Literacy strategies for all students—think; reason; view; represent through pictures, graphs and text; read; activate prior knowledge; use expository texts and narratives that relate to students' lives; select well-planned comprehension questions about inquiry activities and texts; write narrative and expository pieces on science-related topics; model and teach academic language functions; use graphic organizers that support science concepts and literacy goals.
2. Language support strategies to use with ELLs—hands-on, inquiry-based activities; use different ways to represent information, objects, events; modeling; demonstrations; use of pictures, graphs and drawings; explicit teaching and incorporation of vocabulary; expect students to use vocabulary.
3. Discourse strategies to support ELs—adjust language load to help ELs participate in learning and still maintain high rigor; clearly enunciate; use examples and different ways to explain; challenge students a little past their language level; refine students' understanding of science concepts; support understanding using positional words, comparative words and affixes.

4. Home language support—teachers who share the same language background as students can use their shared language to communicate important ideas; other students can help students with lesser language abilities; important science vocabulary can be introduced in home language as well as English; point out cognates.
5. Home culture connections—ask questions of students about their experiences and how they relate to science concepts; use of cultural artifacts and connections in the community that bring relevance to the curriculum; understand the role that culture plays in how students participate and interact in the classroom; validate and bridge behaviors so that students feel a sense of belonging and have the opportunity to learn the cultural norms of the classroom.

Appendix B

Seven Phases of Open-Inquiry

According to Van Uum, Verhoeff and Peeters (2016), teachers can use specific interventions to lead primary students through the seven phases of the open-inquiry process. Throughout these phases, there are ample opportunities to develop and engage the four domains of language. Inquiry-based science is a platform to accomplish both science and language goals.

In the introduction phase, students are introduced to a science-related problem or a phenomenon. Ideally, this introduction should hook students' interest and get them wondering about the science topic.

The second phase is exploration where teachers ask questions of the students that get them to articulate what they already know and think about the science topic. This phase also includes activities that introduce important concepts students need to know in order to reason through the science investigation. Activities and assignments that allow them to construct and build their knowledge are helpful in getting students to connect the new information to the old. These activities are led through questions. Students can watch videos, read articles, and create posters.

In stage three, students design the investigation. The teacher leads students through the process of designing a research question and helping students think through the tools they will need to collect information and measure the results. The teacher also highlights and teaches the importance of communication and collaboration as students work together.

Phase four is when students conduct the investigation. The teacher's role in this step is to explain how to collect proper data, provide adequate practice and allow students to evaluate the pros and cons of their data-collection method.

Drawing conclusions, phase five, is where students analyze their data and bring meaning to them. They can see how the data answer their research question. It is often difficult for students to separate the data from their opinions. This is where a teacher can help them see the data for what it shows—nothing less and nothing more.

In phase six, student prepare a presentation and communicate the knowledge to an audience.

Phase seven is a final opportunity to reflect on the inquiry process and to see how their research findings connect to larger science themes.

Inquiry Continuum

Banchi & Bell (2008), describe the four levels of inquiry. On one end of the continuum is a highly structured experience where more information is given to students. On the other end of the continuum, students do most of the investigating and less information is provided to them.

At the first level—confirmation inquiry—the task, method for testing and answers are already determined. Students practice their skills at arriving at the results that they should get.

At the second level—structured inquiry—the teacher determines the question and method, but the students use data and knowledge to answer the inquiry question.

The third level of inquiry—guided inquiry—only the question is presented to students. Students must determine the method, collect results and articulate an explanation. Students are most successful with this when they have had ample opportunities to plan and execute various methods of data collection.

The last level of inquiry is open inquiry. This is where students articulate their own questions, design their methods, conduct the experiment and communicate the results. Many Full Option Science Systems (FOSS) curriculum units used by elementary schools are structured along this inquiry continuum.

Appendix C

Finding Common Ground Between Worldviews

Aikenhead and Ogawa (2007) advocate for teachers to build on the common ground that differing worldviews share. In their article, they presented in table-format, information that originated from Stephens's (2000) comparison of two worldviews—traditional native knowledge and western science. While neither worldview is monolithic or static, the information contained in Table 7 offers one example of where common ground can be identified in order to validate the knowledge of diverse learners, provide a bridge to mainstream content, and enrich the classroom with added perspective.

Table 7
Stephens's (2000) similarities and differences between traditional native knowledge and western science

(Themes)	Traditional Native Knowledge	Common Ground	Western Science
Organizing principles	• holistic • includes physical & metaphysical world linked to moral code • emphasis on practical application of skills and knowledge	• universe is unified • body of knowledge stable but subject to modification	• part to whole • limited to evidence and explanation within physical world • emphasis on understanding how
Habits of mind	• trust for inherited wisdom • respect for all things	• honesty • inquisitiveness • perseverance • open-mindedness	• skepticism
Skills and procedures	• practical experimentation • qualitative oral record • local verification • communication of metaphor and story connected to life, values, and proper behavior	• empirical observations in natural settings • pattern recognition • verification through repetition • inference and prediction	• tools expand scale of direct and indirect observation and measurement • hypothesis falsification • quantitative written record • global verification • communication of procedures, evidence and theory
Knowledge	• integrated and applied to daily living and traditional subsistence practices	• plant and animal behavior, cycles, habitat needs, interdependence • properties of objects and materials • position and motion of objects • cycles and changes in earth and sky	• discipline-based • micro and macro theory (e.g., cell biology and physiology, atomic theory, plate tectonics, etc.) • mathematical models

Appendix D

Treatment Sequence

Most of the participants lacked adequate understanding of erosion and deposition as assessed by the post-instructional test. Based on the data collected, I created this mini-lesson sequence to address the knowledge gaps and to tailor treatment sessions to individual student.

I. What is a *landform*?

1. Define landform (show visual).
2. Participant sorts landforms/non-landform pictures.
3. Participant defines *landform*.

II. What is a *natural process*?

1. Define process (show visual).
    1. Give example of brushing teeth.
    2. Participant gives example of process (e.g. getting ready for school).
    3. Participant defines *process*.
2. Define *natural process*.
    1. Share example of how ice/glaciers change the earth (show visual).
    2. Participant describes how wind can change earth (show visual).
    3. Participant defines *natural process*.

III. What are *earth materials*?

1. Define earth materials (show visual).

    1. List earth materials (show visual).

    2. Participant describes what *earth materials* are.

IV. What is *erosion*?

1. Define erosion (show visual).

    1. Participant describes how pictures are different.

    2. Read definition/check for understanding.

2. Participant describes *erosion*.

V. What is *deposition*?

1. Define deposition (show visual).

    1. Participant describes how pictures are different.

    2. Read definition/check for understanding.

2. Participant describes *deposition*.

VI. Connect ideas to real world example: canyon

1. Define canyon (show picture).
2. Give explanation: A canyon is formed when a river erodes the earth. This happens slowly over millions of years. The fast-moving water erodes/picks up earth materials and moves them to a different place (downstream). More and more land is eroded until a deep canyon is formed.
3. Participant explains how a canyon is formed using the appropriate vocabulary (on visual).

VII. Connect ideas to real world example: delta

1. Define delta (show picture).

2. Give explanation: A delta is formed when water slows down at the mouth (end) of a river. A delta is in the shape of a triangle. At the end of a river, fast moving water slows down. The heavier earth material, like rocks/pebbles, is deposited/dropped first. The lighter earth material, like sand or soil, is deposited/dropped off last.
3. Participant explains how a canyon is formed using the appropriate vocabulary (on visual).