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SFL In The Secondary Classroom: Writing Procedural Recounts To Describe Thinking When Solving Algebraic Equations

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SFL IN THE SECONDARY CLASSROOM: WRITING PROCEDURAL RECOUNTS
TO DESCRIBE THINKING WHEN SOLVING ALGEBRAIC EQUATIONS

by

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A capstone submitted in partial fulfillment of the
requirements for the degree of Master of Arts in English as a Second Language

Hamline University
St. Paul, Minnesota
May 2017

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To my curious and determined students who inspire me everyday. To my growth-minded classroom colleagues who are always willing to try a new idea. To my supportive and steadfast Capstone Committee whose collective knowledge and expertise helped me develop my skills as a researcher. To my enthusiastic parents, children and friends who loyally saw me through this journey. Finally, to my loving and supportive husband for believing in me and making room in our lives for this endeavor.
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CHAPTER ONE: INTRODUCTION

Meeting the needs of the diverse English Learners (ELs) in America’s secondary schools has many unique challenges. Unlike elementary ELs who begin learning to read and write in English at the same time as they begin their formal schooling, secondary ELs attend school with 12 or more years of language development and a variety of academic or formal schooling experiences. In general, these students learn basic communication skills in English with considerable deft, however, academic reading and writing skills require more time and explicit instruction. Additionally, secondary ELs have a shorter timeframe in which to reach English language proficiency, graduate from high school, and become college or career-ready. Consequently, their English skills must be learned while simultaneously learning content area standards.

One instructional model that is used to meet the needs of secondary ELs is co-teaching, in which an ESL teacher and a content teacher share a classroom and class of learners and, depending on the school and the size of the EL population, that class of students may include both ELs and non-ELs. The challenge within this program model is how to blend language development instruction into content area instruction. While this practice may seem more readily adaptable in language and literature courses, writing cross-curricularly is a neglected but important component to content learning (National Commission on Writing, 2006).
In this study, I will explore whether language development, using the theoretical base of Systemic Functional Linguistics, can be taught within the context of secondary math content. Specifically, I will conduct a case study of seven ELs and three non-ELs who are explicitly taught to write a procedural recount, to discover if learning this strategy will enable students to describe their thinking and justify their answers when solving math problems. I endeavor to discover if teaching such a strategy will increase both their academic writing skills and math understanding.

Diverse English Learners in Secondary Schools

Secondary ELs in the US come with a broad range of academic and life experiences. In order to meet the needs of these learners, schools implement an ESL program that fits its unique population. In contrast to elementary ELs, secondary ELs have a shorter timeframe in which to become proficient and graduate from high school “college or career ready.” Many factors influence an individual EL’s ability to achieve English language proficiency (ELP) including transience or interrupted formal education, socioeconomic status, L1 literacy or whether or not English was studied as a foreign language. The unique situation of each EL plays a role in how many years it takes to achieve ELP. Assessments such as the World Class Instructional Design and Assessment’s (WIDA) assessing comprehension and communication in English state-to-state (ACCESS) measure students’ abilities across four language domains: reading, writing, speaking and listening. Often, a school’s criteria for graduating from an ESL program relies heavily on ELP scores.

There is mounting concern for a subset of secondary ELs who were born in the US and have attended public schools in the US, yet their academic ELP level, based on
the ACCESS or other assessments, stagnates between 3.5 and 5 out of 6 (Menken, Kleyn & Chae, 2012; Walker, 2015). While these students often develop strong social English language skills, they struggle with the demands of academic English and are at high risk for dropping out of high school before graduation (Menken et al., 2012; Walker, 2015). They are considered Intermediate-Advanced ELs with strong skills in the oral and listening modalities, but much weaker within the writing and reading modalities which prevents them from meeting the criteria necessary to graduate out of ESL programs. It may also hinder their success within content area courses and achievement on high stakes standardized assessments.

**Psychosocial Effects on Secondary ELs**

One thing that all secondary learners share is their developmental stage of life: adolescence, and the physical and psychosocial aspects of growing from childhood to adulthood. Secondary students are naturally creating their identity and have a strong desire to fit in with their peers. However, as Harklau (2000) describes, the EL label can be problematic because it separates ELs from their NL peers and holds a negative connotation due to the implied deficiency of the label. Secondary ELs feel stigmatized and strongly resist this representation. My experience confirms this. EL students with strong oral and listening skills do not understand why they continue to be labeled as “English Learners.” Many of my students report that they think of English as their first language, and that they are more literate in English than their home language. Nevertheless, the institutional EL label is used until they meet the ESL program exit criteria, hopefully equipped with the skills to succeed in the US educational system. The dissonance between student perception of themselves as fluent in English and the
institutional meaning behind the EL label effects their psychosocial well-being (Capps, Fix, Murray, Passel, 2005; Harklau, 2000; Walker, 2015).

By contrast, newcomers more easily understand their identity as an EL and are naturally more dependent on specialized language development classes, however they may feel isolated without social language to form friendships and there is a risk that they are missing important content learning if they are separated from same-age peers. Furthermore, academic English skills are required in order to learn secondary content standards and demonstrate knowledge. From the secondary school’s point of view, the ability to offer appropriate coursework for this diverse set of ELs is difficult, especially given the compartmentalized nature of secondary education. Nonetheless, the Minnesota Learning English for Academic Proficiency and Success Act (LEAPS, 2014) legislation requires that schools find ways to meet these students’ needs and ensure that language is not a barrier to learning.

**Co-Teaching Model**

Co-taught content-area classes, where an ESL teacher joins a content-area teacher to create and teach lessons which focus on both the language of the content area as well as the content standards, are emerging as a program model option to meet the diverse needs of secondary ELs. In co-taught classes, ELs join their non-EL peers in mainstream classes while continuing to receive instruction in critical academic language development. This focus on the language of the content area not only makes the content more accessible for ELs, but non-EL students also benefit because the secondary level language demands increase in complexity. Co-teaching more naturally finds its way into language and literature classes or social studies where reading and writing demands are
apparent. Math classes are often identified as a content area class in which to begin mainstreaming ELs due to the misconception that the language demands are less onerous because of the universal nature of numbers and calculations (Schleppegrell, 2007). However, the multi-semiotic nature of math language actually requires students to find language to describe abstract concepts resulting in complex language structures and highly specialized vocabulary (Bresser, Melanese, & Sphar, 2009; Schleppegrell, 2007). Progressive math curricula recognizes this and places more emphasis on vocabulary and using language to describe both concrete and abstract processes, in accordance with learning theories which posit that a students’ conceptual understanding increases when language can be used as a tool to describe abstract concepts (Bresser et al., 2008; Moschkovich, 2013; National Commission on Writing, 2006). Therefore, co-teaching in the math class is relevant and valuable.

**Connected Mathematics Project (CMP)**

One such progressive math curriculum is the Connected Math Project (CMP). This curriculum has its origins in the *Middle Grades Math Project* (MGMP) and was developed over a period of ten years with funding from the National Science Foundation at Michigan State University. With collaboration from teachers and leaders across the country, the first edition of Connected Mathematics (CMP1) was launched in 1991. A revision of the curriculum (CMP2) was made and published in 2000. Ten years later, in 2010, with the release of the Common Core State Standards for Math (CCSSM), CMP2 was revised and CMP3 was developed (Connected Mathematics Project (n.d.-a)). The CMP philosophy is rooted in research which emphasizes the “interplay between conceptual and procedural knowledge” and that “sound conceptual understanding is an
important foundation for procedural skill” (Connected Mathematics Project, n.d.-c, para.10). Thus, the CMP curriculum strongly emphasizes math discourse and cooperative learning techniques which encourage learners to communicate their conceptual, mathematical processes and understanding (Connected Mathematics Project, n.d.-b).

**Systemic Functional Linguistics - Procedural Recounts**

Systemic Functional Linguistics (SFL) is an approach to language which looks at the linguistic features of various genres of text and organizes the meaning-making parts of language. Developed by Michael Halliday in the late 1970s, SFL has influenced second language acquisition pedagogy in Australia and more recently, it is gaining hold in the United States. When using SFL analysis as a pedagogical tool within a math curriculum, identification of language features that are critical to understanding meaning in mathematics takes place. For example, the language for explaining ‘how and why’ is needed to communicate mathematical thinking processes. According to Derewianka (2012), these features include sequencing language (first, then, next, after that), language for justification (because, so that, in order to) and verbs that convey “doing” and "thinking" processes. SFL provides a framework to approach writing in math through the genre of procedural recount. For this study, a math writing intervention is used to explicitly teach students the language necessary to describe their thinking when solving math equations through writing procedural recounts. In this way, I seek to understand whether this writing strategy will both help students deepen their conceptual understanding of solving math problems as well as increase their English writing proficiency.
Role and Background of the Researcher

I am an ESL teacher in a first-ring suburb of a large metropolitan area. The EL population is roughly 10 percent of the approximately 4500 district enrollees. The middle school where I teach enrolls about 1000 students grades six to eight, and reflects the same percentage of EL students, or about 100 ELs. The school has recently been accredited as an International Baccalaureate -Middle Years Program (IB-MYP) school.

The majority of our ELs speak Spanish or Somali as their home language. Our ESL program is designed to meet the language development needs as well as the psycho-social needs of our students. Based on their language proficiency levels, students receive ESL services in three ways: A Beginner (newcomer) ESL Class, a reading intervention class, and co-taught math and social studies classes. Depending on proficiency levels and schedule limitations, these co-taught classes may be the only ESL services they receive.

I co-teach in the math department, collaborating with an 8th grade math teacher and a 7th grade math teacher. Together, we design lessons based on state math standards and language development and literacy targets. Our school made the decision to add language support directly into math classes with the goal of increasing EL students’ ability to understand the content, make connections between concepts, and increase math proficiency to grade-level standards. The language of math causes more difficulty for ELs than non-ELs (Martiniello, 2008; Moschkovich, 1999; Schleppegrell, 2007). Taking into account research and resources, we follow best practices to modify instruction and assessments to meet their needs and allow them to show us what they know. Certainly, the math teachers are aware of the academic language challenges presented in math, and have incorporated many best practices into their classroom including word walls, focus
on vocabulary, small group tasks, etc. As the ESL teacher, I stretch beyond these practices to include language-rich activities that give students practice in math discourse and reading for meaning.

However, while increasing achievement in grade-level math standards is a worthy goal, I am also interested in increasing ELs’ language proficiency with a specific emphasis on academic reading and writing skills that will help them to achieve the English language proficiency criteria so they can graduate from the ESL program. I was compelled by Walker’s 2015 study, which confirmed my observations of the proficiency data trends that I noticed where students who retain an ESL classification after 6th grade tend to lag in the reading and writing modalities. I was further alarmed at Walker’s data which indicates that long-term EL students (LTELLs) who exit ESL services in 9th grade have a dismal 59% rate of graduation. My students were at serious risk for dropping out of school! Additionally, my school administrators were asking why we have students who have been schooled in our district since kindergarten but who are not exited from ESL services in the typical six to seven years. I resolved to find new ways to increase academic writing skills where I had some influence: in the math classroom. While there existed plenty of research into math reading and comprehension, I found very little research on building writing language lessons and objectives into the secondary math curriculum.

**Guiding Questions**

This project explores whether explicit instruction in writing procedural recounts helps learners to describe and effectively communicate their mathematical thinking. The specific research questions are: After explicit instruction, do students choose language
structures inherent to procedural recounts, such as technical verb processes, precise nouns, sequence words and causal phrases to describe their mathematical thinking? Additionally, do student self-perceptions of their mathematical abilities change after learning to write procedural recounts to describe their thinking processes?

**Summary**

In this classroom research study, I’m studying whether an explicitly taught writing strategy, incorporated into a secondary level (grade eight) math curriculum will increase English Language writing skills and math conceptual understanding for students. The results of my study will be of interest to several groups. First, students will learn whether writing procedural recounts helps them to clarify their thinking around the process of solving math equations, which in turn could potentially increase their conceptual understanding of math. Administrators and math teachers will gain insight into how explicitly teaching all students (ELs and non-ELs) to describe their mathematical thinking processes increases their facility with academic language and math terms as well as whether writing procedural recounts affects student perceptions of conceptual understanding of math. Finally, ESL teachers will learn an instructional approach to writing using the SFL genre procedural recount as well as an example of assessing language use in the content areas. Additionally, if effective, this math writing strategy could positively affect learner performance on high-stakes, standardized math and language development assessments. Ultimately, writing procedural recounts in the math classroom could help Intermediate-Advanced EL students achieve English language proficiency before they enter the rigors of high school and beyond.
In Chapter Two, I will review the current literature that pertains to mathematical language, EL and non-EL achievement gap, and pedagogical responses. In Chapter Three, I will describe the methodology for my classroom research study in which student participants are explicitly taught to write procedural recounts to describe their thinking when solving math problems. In Chapter Four, I will present the data collected from my classroom research project and finally, in Chapter Five, I will summarize my findings and present additional research questions.
CHAPTER TWO: LITERATURE REVIEW

The purpose of this study is to investigate whether an explicitly taught writing strategy, incorporated into a secondary level (grade 8) math curriculum will increase EL students’ ability to effectively describe their thinking processes in writing, as well as deepen their math conceptual understanding. This chapter will review the literature relevant to the various subtopics related to the language of mathematics. I begin with a close examination of the research that has accumulated with regard to the language of mathematics and the meaning-making systems that exist. This section includes a brief overview of Michael Halliday’s linguistic theory of Systemic Functional Linguistics (SFL). Next, I present the measurable effects that this complex language system has on ELs’ ability to learn math, including achievement gap data between native and non-native speakers of English on standardized math proficiency tests. Further, I will explore the psycho-social effects that arise when academic struggles are not appropriately addressed. From here, I will review some progressive pedagogical responses to the achievement gap. It is in this section, Pedagogy, where I identify a gap in the research. Much of the research in math and language pedagogy investigates instructional strategies that focus on specialized vocabulary and syntax in order to improve reading comprehension of math word problems. However, much less is known about pedagogical strategies for eliciting productive (oral and written) language in the math classroom. According to the research, an ability to communicate mathematical thinking not only improves oral and written
language skills but is critical to gaining a conceptual understanding of math. This literature review will demonstrate the need for finding more effective ways to incorporate productive language skills in the secondary mathematics classroom. Research questions for this study are: After explicit instruction, do students choose language structures inherent to procedural recounts, such as technical verb processes, precise nouns, sequence words and causal phrases to describe their mathematical thinking? Additionally, do student self-perceptions of their mathematical abilities change after learning to write procedural recounts to describe their thinking processes?

**Language of Mathematics**

From a linguistic perspective, the language of math is constrained and challenging, in part because it requires that learners move from informal, everyday language toward technical, academic language in order to fully understand the math concepts (de Oliveira & Cheng, 2011; Schleppegrell, 2007). This creates difficulties for all learners, but particularly for ELs for whom learning language and learning math is a simultaneous process. ELs struggle with math language because it often uses complex sentence structures and vocabulary rich with low-frequency words or words with multiple meanings found outside the context of math. Evidence of this is seen through results from the National Assessment of Educational Progress (NAEP) Mathematics Assessments, which show that from 1996 to 2007, 92 percent of ELs scored below “proficient” on average, as compared to 68 percent of non-ELs (U.S. Department of Education, 2007, as cited in Martiniello, 2008).

In understanding the situational context of math language, it is helpful to examine what linguistic researchers have determined to be the multi-semiotic nature of math
language. Math uses several semiotic or “meaning-creating” systems in order to communicate mathematical concepts. These semiotic systems include written language (text), symbols and visual representations (=, -, x, *, %, graphs, tables, diagrams) and oral language (teacher/student discourse) (de Oliveira & Cheng, 2011; Schleppegrell, 2007). This multi-semiotic approach to math was developed and is used because math concepts go beyond what ordinary language can express (O’Halloran, 1999). Learners, therefore, must be able to cross-reference and shift between these systems in order to construct meaning (Schleppegrell, 2007).

**Math Language Input - Reading Textbooks and Assessments**

In mathematics, learners encounter written language by way of textbooks and assessments. The linguistic complexities of this language occur in two areas: vocabulary and complex sentence structure. Math vocabulary includes precise, technical and academic terms such as *sum* or *fraction*. However, it also includes words which have both a mathematical meaning and other meanings in everyday language such as *place*, *borrow* or *product* (examples taken from Schleppegrell, 2007). These polysemous words, or words with more than one meaning, are particularly difficult for ELs as learning new meanings for words that students already know in one context may be more difficult than learning new and unfamiliar technical vocabulary (Schleppegrell, 2007). In her textual analysis of the Massachusetts Comprehensive Assessment System (MCAS), Martiniello (2008) examined the math word problems used on Grade Four tests and found that vocabulary issues (polysemous words, academic words and cultural background words such as *chores* or *babysit*) caused a significant differential in scores between ELs and
non-ELs, raising the question whether these tests are accurately assessing ELs’ math knowledge (Martiniello, 2008).

Besides these pragmatic aspects of the vocabulary of math, researchers point to grammatical challenges in the written language of math that also have pragmatic implications. Complex sentence structures, long noun phrases, and specialized language patterns are common features found in the language of math textbooks and on tests (de Oliveira & Cheng, 2011; Martiniello, 2008; Schleppegrell, 2007). In her analysis, Schleppegrell (2007) found that the grammatical structure of sentences in math texts contain dense noun phrases that include classifying adjectives and qualifiers before and after the noun (e.g., the volume of a rectangular prism with sides 8, 10 and 12 cm). In this example, the head noun: prism is preceded by both a quantifiable, mathematical attribute: volume and a classifying adjective: rectangular. This noun is followed by yet more qualifiers: with sides 8, 10 and 12 cm. (examples from Veel, 1999, as cited in Schleppegrell, 2007). Complex noun phrases such as this example require a high level of linguistic awareness in order to comprehend its meaning. As Schleppegrell (2007) points out, there is heavy use of nominalization whereby mathematical processes are presented as things because they can appear as nouns or noun phrases within a sentence (e.g., the volume of is a noun phrase but implicitly refers to a process of calculating the volume). In addition, ELs must learn the meanings of specialized language patterns used frequently in math to signal relationships such as more than, less than and as many as (examples from Schleppegrell, 2007). In short, ELs must be able to decipher complex language structures, long noun phrases and specialized language patterns within the context of
solving math problems in order to comprehend their meanings as they apply to mathematics.

**Math Symbols and Visual Representations in Context**

Symbols are used in math language to encode meaning from everyday language into an efficient and unambiguous expression of meaning (de Oliveira & Cheng, 2011). Each symbol represents a specific function or relationship between mathematical elements in a standard and conventional way. Brackets and parentheses govern how symbols are used and provide the logical reasoning for the pattern of these relationships through the rules called “order of operations” (de Oliveira & Cheng, 2011; Schleppegrell, 2007). For ELs however, ambiguity may still exist due to differences in cultural background knowledge. For example, there are several symbolic representations of multiplication: $x$, $\times$, *a number in front of a variable* (e.g., $3x$), or *a number beside a parenthesis* (e.g., $4(x+1)$). Parentheses, another frequently used symbolic construct in math, have a specific meaning and function within the context of a math equation compared to a non-math context. These examples demonstrate the existence of implicit meanings that symbols convey within the context of math that ELs must understand and make explicit in order to fully comprehend the math content as well as describe their process for solving math problems.

**Language Output - Oral Discourse and Written Language in the Classroom**

In mathematics, math discourse, or the oral language component, is the system that bridges the written language, symbols and visual representations with the comprehension and understanding of the concepts (Schleppegrell, 2007). In the
classroom, teachers use oral language to describe the meaning of math concepts in everyday language and to model the use of the technical language. In addition, math discourse between teacher and learner or learner and learner provides the opportunity and flexibility for learners to interact with the language vocabulary and structures. This interaction is needed in order to practice moving between the everyday and the technical language needed to fully comprehend its meaning (Barwell, 2005; Schleppegrell, 2007). In addition to oral discourse, student participation in writing tasks such as “explaining solution processes, describing conjectures, proving conclusions and presenting arguments” develops student use of the technical language of mathematics and helps both the learning of mathematical concepts as well as demonstrating their mathematical knowledge (Moschkovich, 1999, p. 11). However, in her study of third grade learners, Fortescue (1994) found that multiple experiences with both teacher modeling and student discourse led to writing that used more technical mathematical language.

**EL Achievement Gap**

A persistent achievement gap in the United States between ELs and their non-EL peers is well documented through national standardized measurement tools. In a recent study, Walker (2015) breaks down standardized achievement data within the EL population to study differences between those who exit ESL services and those who do not, given their English language proficiency assessment scores and other factors that determine ESL Program Exit status. Among the variables Walker uses to conduct the discriminate analyses are English language proficiency scores from the WIDA ACCESS exams, state standards proficiency assessments, Measure of Academic Progress (MAP) test benchmark scores, Initial English Proficiency, and the number of years in the US
education system. Additionally, risk factors such as attendance, transiency, suspension and retention are included. Walker’s data is collected across three grade levels: 3rd, 5th and 9th grades. Her study finds that even when adjusted for all risk factors, the ACCESS scale scores, which measure academic English proficiency, had the highest predictive power for high school graduation. In 3rd grade, the ACCESS scores across the domains of reading, writing and listening were strongest predictors. In 5th grade, the strongest predictors for high school graduation were reading and writing scores and 9th grade predictors were the composite comprehension score and the writing score. There is growing evidence that graduation rates are inversely correlated with the number of years an EL spends in a language development program (Walker, 2015), increasing the stakes for middle school language development programs. ELs who were reclassified in 3rd grade have a graduation rate of 82%, those reclassified in 5th grade had a 72% graduation rate and those reclassified in 9th grade had a 59% graduation rate (Walker, 2015). The findings in this study confirm the need to address English academic language proficiency with a focus on academic writing and content area learning in the secondary schools.

**EL and Non-EL Math Achievement Gap**

The achievement gap in math and reading between ELs and non-ELs is well known and persistent. Data from the National Assessment of Educational Progress (NEAP), or the “nation's report card” in mathematics reveals the average gap between ELs and non-ELs over the past ten years (2005-2015) in math achievement was 24.5 points for 4th grade and 39.7 points for 8th grade (U.S Department of Education, National Center for Educational Statistics, 2015). Similarly, the average scores and achievement level results in NAEP mathematics for 4th grade as reported in 2015 show
57% of ELs were “at or above Basic” math proficiency while 84% of non-ELs score “at or above Basic” level. In 8th grade, the statistics show an increasing gap between ELs and non-ELs: only 31% of ELs were “at or above Basic” proficiency in math while 73% of non-ELs score at that level. These statistics show that as students move from primary to secondary grades, the math achievement gap widens. Among other things, this growing achievement gap reveals the increasingly demanding academic English and math language needed for secondary math content understanding. The implications from studies comparing ELs and Non-ELs' standardized math scores underscore the importance of combining language and math instruction (Martiniello, 2008).

**The Connected Mathematics Project (CMP)**

Since the late 1980s, reform programs by the National Council of Teachers of Mathematics (NCTM) have placed a greater emphasis on mathematics literacy (Hansen-Thomas, 2009; Spanos, 2009). These reforms were prompted by a rapid change in student demographics; the non-U.S. born student population increased by 25% over a ten year period between 1980 and 1990 (Waggoner, 1999), as well as a co-occurrence of poor performance on standardized math assessments.

The Connected Mathematics Project (CMP) math curriculum was developed during a reform period with the pedagogical philosophy of “engaging students in making sense of mathematics” (Connected Mathematics Project, n.d.-a). In response to the Common Core State Standards in Math (CCSSM) published in 2010, CMP underwent its third revision. The current curriculum emphasizes a constructivist approach to learning

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1 Basic denotes partial mastery of the knowledge and skills that are fundamental for proficient work at a given grade.
and acknowledges a “growing body of research indicating that when students engage in cooperative work on challenging problem solving tasks, their mathematical and social learning will be enhanced.” (Cohen, 1994, as cited on Connected Mathematics Project., n.d.-c, para.4). Therefore, CMP curriculum is focused on classroom discourse, cooperative learning groups, higher-order questioning and elicitations of student to explain their thinking (Connected Mathematics Project, n.d.-a).

Many linguistic researchers concur that there is great advantage to leveraging classroom discourse in math (Hanson-Thomas, 2009; Moschkovich, 1999; Schleppegrell, 2007). Hanson-Thomas’ (2009) ethnographic case study of six Latino middle school ELs’ participation in mathematics discourse found that students who were successful in math generally spoke more, and employed more complex language functions such as giving a rationale, verbalizing solutions to math problems, evaluating and questioning. These students received explicit instruction in how to develop their mathematical discourse. These results suggest a focus on mathematical language and elicitation benefits the development of mathematical discourse and content knowledge. In this way, students not only learn the mathematical register but also learn how to use the terms to describe thinking processes and conjectures, proving conclusions and presenting arguments (Schleppegrell, 2007).

**Systemic Functional Linguistics**

As the Common Core State Standards push math pedagogy toward a more holistic and conceptual understanding of math, there is an opportunity for ESL pedagogy to respond by highlighting the role that language plays in synthesizing ideas and describing ways of thinking and approaching mathematics. As noted above, the CMP curriculum
encourages students to explain their thinking when solving math problems in order to deepen conceptual understanding; however, in order to do this, secondary mathematics requires that learners move from an informal, everyday language toward a technical, academic language (de Oliveira & Cheng, 2011; Schleppegrell, 2007). This is difficult for all learners, but particularly for ELs for whom learning language and learning math is a simultaneous process (Schleppegrell, 2007). Therefore, it is imperative that ELs are taught how to respond to elicitations to describe their thinking processes when solving math problems.

Linguistic researchers have found that Systemic Functional Linguistics (SFL) theory (Halliday & Matthiessen, 2004) provides a framework for analyzing syntax and extended discourse practices used to describe mathematical thinking (Humphrey, Droga & Feez, 2012; Fang & Schleppegrell, 2008). Specifically, a procedural recount writing genre provides a way to organize the language used to express and connect ideas around practical learning experiences (Humphrey et al., 2012). Additionally, SFL provides a metalanguage to use as a way of scaffolding our teaching about the language of math (Dare, 2010) and introduces a schematic structure, in this case a procedural recount, for academic writing. Since SFL theory approaches language from the perspective of linguistic purpose and meaning, writing about mathematical thinking follows the structure of a recount, with its three stages: Orientation, Sequence of Events, and Evaluation (Schleppegrell, 2010). These titles indicate the language choices inherent to the shape of a recount text. For example, in a mathematical procedural recount, the orientation might include circumstances of time/place, or syntactic structures such as past tense noun phrases. The Sequence of Events utilizes technical ‘doing verbs’
(mathematical processes such as add, subtract, multiply, apply, etc.) or ‘thinking verbs' (cognitive processes such as notice, evaluate) as well as words used for sequencing processes or events (first, then, next, after that, finally). The Evaluation stage incorporates language used for justification and reasoning, such as conjunctions, (because, so that, in order to, since, based upon, as a result) for a mathematical proof. (Derewianka, 2012; Humphrey et al., 2012; Schleppegrell, 2007).

While some forms of writing procedural recounts have been studied in science lab reports (Canfield, 2013, Spanos, 2009, Humphrey et al, 2012) or literary instructional settings such as book reviews (Aguirre-Muñoz, Chong & Sanders, 2015; Canfield 2013), few investigations have explored the genre (writing procedural recounts) in secondary mathematics. As we have seen, research supports the notion that when math students have multiple experiences communicating a math concept, and are taught how to write in factual rather than narrative modes, such as procedural recounts or justifications, they not only improve their writing skills but also deepen conceptual understanding (Schleppegrell, 2007). Math pedagogy is responding to this research by asking students to explain their thinking and SFL theory is a useful tool in the development of pedagogical approaches to teaching students to use language to explain their thinking and deepen conceptual understanding while solving secondary math problems (Derewianka, 2012; Schleppegrell, 2007).

**The Gap**

Most of the research and pedagogical strategies developed for teaching math to ELs has focused on middle-elementary years (Barwell, 2005; Canfield, 2013; Coffin, 2010; Fortescue, 1994; Martiniello, 2008). Very few studies examine secondary math.
Likewise, while vocabulary, semiotic systems and reading comprehension have been investigated (Martiniello, 2008; Schleppegrell, 2007; Sweeney, 2014), much less is known about how the writing domain influences student development and understanding of secondary mathematics language and content. Additionally, little emphasis is placed on output (speaking and writing) and instead the focus is on reading comprehension (Sweeney, 2014). Previous research on the role of language in mathematics has focused on vocabulary or technical terms in math (Adams, 2003), overlooking the importance of extended discourse.

**Research Questions**

In light of the research presented in this literature review, we see that the language of mathematics is linguistically complex and becomes increasingly so with the introduction of more conceptually demanding tasks at the secondary level. ELs who have not reached English language proficiency by grade 7 not only see the gap widen between their standardized assessment scores and their non-EL peers but also become at risk for dropping out of school. Schleppegrell (2007), Derewianka (2012) and others agree that multiple experiences communicating a math concept, for example, writing a factual account or a procedural recount or justification, will not only improve English writing skills but also deepen conceptual understanding. This study attempts to apply SFL theory to create explicit instruction in writing procedural recounts to teach students the language used to explain their mathematical thinking processes. The two research questions in this study are: Do students choose language structures inherent to procedural recounts, such as technical verb processes, precise nouns, sequence words and causal phrases to describe their mathematical thinking? Additionally, do student self-perceptions of their
mathematical abilities change after learning to write procedural recounts to describe their thinking processes?

**Summary**

This chapter provides a summary of the current research relevant to the language of math and the increasing linguistic and cognitive demands of learning math at the secondary level. Additionally, statistics which confirm an achievement gap between ELs and non-ELs were presented. Pedagogical responses to the achievement gap in mathematics were discussed and a gap was discovered when searching for sound pedagogical practices which elicit linguistic output in the classroom. In the next chapter, I will outline my research design and procedures for carrying out my classroom research study.
CHAPTER THREE: METHODOLOGY

This study was designed to understand whether students respond to explicit instruction in writing a procedural recount to describe their thinking processes and use this writing genre to describe their thinking around solving grade eight level math equations on a summative assessment. Specifically, this study explored whether students use the language structures and organization inherent to a procedural recount to describe their thinking and whether student use of a writing strategy to explain their mathematical thinking increased their confidence and self-perception of understanding the math concept. This study explored the following questions: After explicit instruction, do students choose language structures inherent to procedural recounts, such as technical verb processes, precise nouns, sequence words and causal phrases to describe their mathematical thinking? Additionally, do student self-perceptions of their mathematical abilities change after learning to write procedural recounts to describe their thinking processes?

This study was designed as classroom research in a naturalistic setting. Both quantitative data in the form of pre-intervention and post-intervention participant writing samples, and qualitative data in the form of a participant self-evaluation on a Likert scale, was collected and analyzed. Participants in this study belong to a standard 8th grade math class in which the majority are ELs. The class is co-taught by a mathematics teacher and myself, an ESL teacher. The school where this study was conducted uses the
Connected Mathematics Project (CMP) curriculum. This curriculum influenced the focus of this study as it encourages students to articulate in writing their thought processes as they solve math problems in order to develop a deeper conceptual understanding of the mathematics being presented. For example, throughout the curriculum, students are asked to explain their thinking or reasoning as they solve math problems. Functionally, a written explanation such as this is an example of a procedural recount. Notably missing in the curriculum is any explicit instruction in how to write a procedural recount. My co-teaching colleague and I developed a set of writing lessons to complement the math curriculum that would become the intervention in this study. The goal of this writing intervention was to teach participants how to write a procedural recount to explain their thinking while solving algebraic equations. Additionally, the lessons would develop language fluency in mathematics and academic English language writing skills, particularly for the ELs, as they are assessed on the writing domain of the WIDA performance definitions and on the WIDA-ACCESS assessment.

**Overview of the Chapter**

This chapter covers the methodologies used in this study, beginning with a rationale and description of the research design. Next, a description of the quasi-experimental qualitative research paradigm is presented. After that, information about the participants in the study, the location and setting of the study and the data collection techniques are presented. Following this are a description of how the data was analyzed, and finally, a discussion of the ethical steps taken to safeguard student participants.
Research Paradigm and Rationale

In order to answer this study's questions, a mixed methods approach to data collection was used, in which both quantitative and qualitative data were collected. To address the first question, writing samples were examined before the explicit instruction (pre-intervention) to determine whether any language structures that are characteristic of a procedural recount were used at the start of the research period. Later, during and after explicit instruction and practice (post-intervention), two additional writing samples were examined and compared. Quantitative data was taken from these samples and was used to measure whether and how much participants chose to use the language of a procedural recount to describe thinking processes when solving algebraic equations independently.

To address the second question in this study, a close-ended self-evaluation questionnaire using a Likert scale from 1-5 (1=no, 2=very little/not much, 3=somewhat, 4=yes and 5=yes, very much!) was used so participants could reflect and answer on a relative basis. Participants responded to questions that asked them to reflect on their learning how to write a procedural recount and its possible effects on their confidence and conceptual understanding when solving algebraic equations.

A quasi-experimental quantitative research paradigm was selected for this study. According to Mackey and Gass (2005), experimental quantitative research is an appropriate tool to utilize when exploring questions of causation. Due to the fact that this study examines whether there is a causal relationship between explicit instruction in a writing genre and a participant’s use of that genre when asked to describe mathematical procedural thinking, experimental quantitative methods, specifically pre-treatment and post-treatment performance are measured. This study collects pre- and post-intervention
data to understand whether explicit instruction in writing procedural recounts to describe thinking while solving algebraic equations increases the quantity of the use of language structures specific to procedural recount writing. Since this is a classroom research study, randomization and control groups were not used, as only one co-taught math class of ELs and non-ELs exists at this grade level at this school. In order to insure authenticity of the writing task, the writing lessons were designed specifically to integrate into the current grade eight math curriculum unit. In this way, both participants and non-participants in the classroom received the writing intervention, which targeted a specific unit of study that all standard grade eight classes currently use.

Additionally, a qualitative research paradigm was used in order to collect data with regard to participants’ perceptions of whether their understanding of writing constructs and conceptual understanding of a math task increases when procedural recount writing is employed during a summative math assessment. According to Mackey and Gass (2005), qualitative research is process oriented and proposes to observe what is present without seeking to fulfill a hypothesis and allowing further questions to emerge. Data collected from the participant self-evaluation questionnaire reflects meta-cognitive awareness which cannot be completely confirmed through participant perception but rather must include data confirming or denying that a participant’s conceptual understanding has indeed increased. The results of a summative math assessment were also used as a data point as a way of looking for confirmation of participant perception of their math understanding.
Data Collection

Participants

Participants in this study were members of a co-taught grade eight math class. A total of 28 students in this class received the writing intervention, engaged in the writing practice, and took the pre- and post-assessments. However, data contained in this study was collected only from those students who opted to participate in the study and have parent/guardian permission to participate.

The total number of participants was 10; seven ELs with ELP levels between 2.1-4.5 out of 6 on the WIDA ACCESS scale and three Non-EL students. Current individual student ACCESS and Minnesota Comprehensive Assessment (MCA) data is shown on Table 1. In some cases, this data is not available because the participant was new to the country within the last year and was exempt from taking the exams. Of the ELs, four are girls and three are boys. Three speak Somali as their native language (NL), two speak Spanish as their NL, one speaks Swahili and the other Vietnamese. Four of the ELs have less than two years in the US and diverse academic backgrounds, ranging from limited and interrupted educational backgrounds to stable, continuous education in their NL and some English as a foreign language. Two of the ELs in this study were born in the US, one of whom has attended this school district throughout their entire academic career. Two of the non-ELs are girls and one is a boy. English is the native language of the non-ELs.
The context for this study was an International Baccalaureate Middle Years Program (IB-MYP) school located in a first-ring suburb of a large metropolitan area in the midwestern United States. This middle school serves almost 1000 students grade six to eight and has about 10 percent ELs. The majority of those 100 ELs are second generation immigrants, born in the US and whose native language (NL) is Spanish or...
Somali, though four of the seven EL participants in this study were born outside the US and immigrated within the last year. The ELP levels of the EL participants range from 2.1-4.5 out of 6. Most of these students do not meet proficiency for state standards in math. This school began using a co-teaching ESL program model for mathematics in 2015-16 school year in part because of concern that a majority of ELs were not meeting state math standards as measured by the MCA assessments. There is one full-time and one part-time ESL teacher on staff. Each ESL teacher co-teaches one section of math in each grade level. Math and other content-area teachers receive professional development training and workshops to develop tools and techniques for teaching a growing population of ELs. The goal of the ESL co-teacher is to identify the academic language needed in order to access the curriculum as well as create lessons with language development objectives in reading, writing, speaking and listening that support ELs’ progress toward reclassification by ninth grade or sooner.

This study was conducted during the 2016-17 school year, during the month of January and within one curricular unit of study. Prior to this unit, language development objectives focused on oral production of academic language. Students were regularly asked to describe with words how they solved a problem.

**Data Collection Technique 1: Pre-Intervention Writing Assessment:**

In the weeks prior to the intervention, participants were taught how to solve an algebraic equation in one variable using the properties of equality, addition and multiplication, as well as arrows, operational symbols and solve and undo (S/U) charts. In order to assess participant’s skills at writing an explanation about how they solved an algebraic equation, the following pre-intervention assessment was given:
“Solve for $x$: 3(2 + 12) = 24 + 4x” Explain.”

Data collection consisted of recording the use of any or all of the following forms of communication: numbers (N); symbols (S), such as arrows or lines; charts (C); and words (W). The sample used an algebraic equation with a similar complexity, degree of difficulty and format to those used for the post-intervention data collection.

**Data Collection Technique 2: Post-intervention Formative/Summative Assessments**

After participants received two explicit lessons on writing procedural recounts, a formative assessment was given in order to gauge whether participants were able to incorporate the elements of a procedural recount into a written explanation independently using a model as a scaffold. There was a final writing lesson before the unit summative exam which included a writing elicitation. In both the formative and the summative, participants responded to the “Solve and Explain” prompt with a similar equation. Participant responses from both the formative and the summative were analyzed and results were compared. In order to compare the writing samples, a point was assigned for each instance that a word or phrase was used in one of five categories: Sequence Words (SW) such as first, next, then, finally etc; Causal Phrases (CP) such as: resulting in, making..leaving me with, in order to, so; Technical Verbs (TV) such as: use, apply, add, subtract, multiply, divide, remove; Common-sense Verbs (CV) such as: did, get/got; Math-specific Nouns or Noun Phrases (MNP) such as: distributive property, x-terms, solution, chart, parentheses, equation; (More than one instance of the same structure in a single sentence was counted as a single token; however, each use of the same structure in different sentences was counted as a separate token.)
Data Collection Technique 3: Self-Evaluation Questionnaire

Upon completion of the curricular unit, participants responded to a self-evaluation questionnaire to determine their perception about the effects of learning to write a procedural recount to describe mathematical thinking. Scores were measured on a Likert scale of 1-5; 1 = no, 2 = very little/not much, 3 = somewhat, 4 = yes and 5 = yes, definitely! The questions on the self-evaluation were read aloud to participants and the scoring scale was described carefully to ensure participant understanding. The questions were:

1. **Before** learning how to write a procedural recount, how much did you know about using precise math words to describe your thinking when solving equations in math?

2. **After** learning how to write a procedural recount, do you have a better understanding of how to use precise math words?

3. **Before** learning how to write a procedural recount, how confident were you about explaining your answers in math?

4. **After** learning how to write a procedural recount, how confident are you about explaining your answers in math?

5. **Do you feel that learning how to write a procedural recount to explain your answers in math helps you understand the math better?**

**Procedure**

The study began at the start of a CMP math curricular unit called *Say it With Symbols*, which introduces the concepts of manipulating symbolic (algebraic) expressions, using the properties of numbers, recognizing equivalencies and reasoning
about relationships. The learning objectives tied to Minnesota state standards for grade eight mathematics are: “Write equivalent expressions and solve multi-step equations in one variable”; and “Justify the steps by identifying the properties of equalities used when solving algebraic equations” (MN 8.2.2.3.2, 8.2.3.2). The math curriculum, which extends over a five-week time period, leads students to discover the equivalencies in symbolic expressions and how to use the properties of numbers to solve for a variable $x$.

Early in the unit, participants were taught how to apply the properties of equality and solve equations. Concurrently, they practiced describing the steps orally while demonstrating how they solved an equation on the whiteboard using symbols, lines and arrows. When participants demonstrated satisfactory proficiency at solving algebraic equations with one variable, the first data collection tool was administered. Participants were given an equation to solve, which was similar in difficulty and complexity to an equation which would be used on the unit summative assessment, and then were told to explain their answer (see Appendix A for a copy of the pre- and post-intervention assessments). This writing sample revealed how participants rely on symbols rather than language to explain their thinking (see Figure 1)

![Sample EL student response on pre-intervention writing assessment.](image-url)
These results were in line with earlier observations of a general inability for most students to write a response to the prompt *explain your answer* and confirmed the need for explicit instruction in writing procedural recounts. In most cases, only symbols such as arrows, math operations and numbers were used to describe their thinking process. Only one non-EL participant used some sequence words to create a loose structure to the explanation. (see Figure 2)

![Image](https://via.placeholder.com/150)

**Figure 2:** Sample non-EL student response on pre-intervention writing assessment.

Based on the results of the pre-intervention writing sample, lessons in writing a procedural recount were developed and used for the intervention which would address: 1) the reasons for writing a procedural recount when solving math problems and being able to communicate thinking processes in an organized way; 2) explicit instruction and modeling of the structural elements of procedural recounts including sequential and causal phrases; and 3) the vocabulary aspects of procedural recounts including explicit use of technical verbs and math-specific nouns. (See Appendix B for an outline of the writing lessons).
The lessons on writing procedural recounts as a tool to explain or describe their thinking in writing were presented to the class over the course of three weeks. Opportunities for practice in writing procedural recounts occurred throughout this period and formative feedback from the ESL teacher was given. The lessons sought to transition participants from using symbolic expressions of math writing and an informal, oral communication style to a more formal style used in written academic texts. Additionally, posters with lists of math-specific words that had been generated by participants throughout the unit hung on classroom walls for reference as needed throughout the unit and during the summative exam (see Appendix C for wall poster content).

After the first two explicit procedural recount writing lessons, a formative assessment was collected and used as data. The results of this writing sample were quantified according to five language structures that are commonly used with procedural recounts according to Humphrey et al. (2012) and Schleppegrell (2007). These include: technical verbs, common-sense verbs, sequence words, causal phrases and math-specific noun phrases. Between the formative assessment writing sample and the summative assessment writing sample, there was a period of two weeks where participants practiced writing procedural recounts, received 30 minutes of additional explicit instruction, received direct, written feedback from the ESL teacher as well as a peer editor using the peer editing checklist (see Appendix D) which encouraged participants to increase the complexity of their writing, for example, recognizing when common-sense words could be replaced with more technical verbs and precise noun phrases. Similar to the formative assessment, the summative assessment included a solve and explain problem. Participant responses from the formative and the summative exams were analyzed and compared. It
should be noted that there was a modified assessment with appropriate scaffolds for level 1-2 beginner ELs (see Appendix E for modified assessment). At the end of the curricular unit and after participants had taken the unit summative exam, a self-evaluation questionnaire was administered to collect data about whether student’s self-perceptions about their math conceptual understanding was affected by writing procedural recounts. (See Appendix F for a copy of the self-evaluation questionnaire.)

**Materials**

**Pre-intervention writing assessment:** (Appendix A)

“Solve for x: \(3(2x + 12) = 24 + 4x\)  Explain:”

This elicitation was designed to assess participants’ current skills at communicating or explaining how they solved an algebraic equation. Earlier in the unit, participants practiced describing how to solve such an equation orally, however, this assessment was the first instance in which they had to explain their thinking in writing. The data collected from this was analyzed and coded according to the ways a student attempted to explain their thinking: 1) with numbers (N); 2) with symbols (S); 3) with charts (C); and with math-specific noun or noun phrase (MNP).

**Writing Lessons:** (Appendix B)

The writing lessons were developed to explicitly teach the language needed in order to write an explanation of one’s thinking/reasoning when solving algebraic equations (see Appendix B for an outline of the writing lessons). In collaboration with the math teacher, an authentic model of a procedural recount was written and analyzed to identify the specific language structures inherent to a written explanation of how one solves an algebraic equation in one variable. The first lesson brought attention to the
language we use to describe a process and justify the steps. The second lesson identified the specific technical verbs and precise math terms we use as we solve algebraic equations, and introduced the structural organization of a procedural recount. The third lesson brought attention to the differences between using oral, everyday language to describe thinking processes and the technical language used for academic writing. This lesson involved peer editing and re-writing with a focus on replacing everyday, common-sense words with more technical math words.

Over the course of the math curricular unit, participants were taught to identify and use the specific language structures of a procedural recount when describing how to solve an equation in one variable. These language structures, organized around the WIDA writing standards framework, include “Linguistic Complexity” and “Vocabulary Usage.” The area of Linguistic Complexity includes the use of sequencing words such as first, next, then, after that, finally as well as causal phrases such as in order to, because, as a result, which left me with...which are used to describe reasoning or justification. Vocabulary Usage includes the use of “technical” math verbs such as the operations add, subtract, multiply, divide, as well as other “doing” verbs such as apply, remove, rearrange, and “thinking” verbs such as notice, evaluate. In contrast to these technical verbs, “common-sense” verbs consist of words used more often in oral language such as get, got, did, as in “I did 2 and 4” meaning “I multiplied 2 and 4” where the common-sense verb “did” is used instead of a the more technical verb “multiplied.” Vocabulary Usage also includes the use of math-specific nouns and noun phrases such as the distributive property, the left side of the equation, the x-terms. These language structures were taught (made explicit) and modeled throughout the writing lessons and math unit.
Lists of these structures were compiled over the course of the unit and posted on the walls of the classroom. The data collection tools, including the pre- and post-intervention writing samples, were evaluated upon these criteria and specific instances of the use of these structures were counted and used as data.

Classroom wall posters: (Appendix C)

Lists of technical math verbs and math-specific nouns and noun phrases were generated by the class during explicit lessons and posted on the walls as scaffolds to writing throughout the unit. Other posters illustrated examples of the how the language structures used in math procedural recounts work together to build complete sentences. All but one of the posters remained on the walls during the summative assessment. The poster which described the properties of equality and how they are used was removed during the summative assessment as it was determined that it would compromise the validity of the mathematics portion of the assessment. (See Appendix C for a description of the student-generated classroom wall posters).

Peer Editing Checklist: (Appendix D)

This checklist was used as a means to bring attention to the specific language used in a procedural recount. Participants used the checklist while peer editing and looked for instances of sequencing words, technical verbs, precise noun phrases and causal phrases in one another’s writing. Then, they re-wrote their explanations. The ESL teacher’s feedback was also based on these writing features. A writing rubric based on the WIDA performance definitions framework for academic writing was introduced to the class but was not used as a means to collect data for this study. Rather, it would serve as a guide to
assess future learning on a continuum, an important aspect to the International Baccalaureate philosophy.

**Post-intervention formative and summative writing assessments:**

Formative assessment: “Solve the following equation and write out in WORDS what you did and why.”

Example:

Sample equation: $3 + 2(4x + 5) + 5x = 94$

Summative assessment: “Solve: $2(7x + 15) = 18 + 2x$ Describe how you solved the equation using precise mathematical language. Be sure to mention which properties you used.”

(Note: The algebraic equation used in the summative assessment is similar in difficulty and complexity to the equation in the pre-intervention assessment and on the post-intervention formative assessment. (See Appendix A for a copy of the post-intervention assessments).

**Self-Evaluation Questionnaire:**

At the end of the unit, and after participants reviewed their results from the summative assessment, they answered the Self-Evaluation Questionnaire (see Appendix F). The questions were read aloud and a five point Likert scale was described orally as well as written on the questionnaire. This was done to ensure understanding of the meaning of the scale.

**Data Analysis**

Language data from the formative and summative assessments was collected and quantified according to the use of language structures in one of five categories: technical
verbs (TV) such as: use, apply, add, subtract, multiply, divide, remove; common-sense verbs (CV) such as: did, get/got; math-specific nouns or noun phrases (MNP) such as: distributive property, x-terms, solution, chart, parentheses, equation; sequence words (SW) such as first, next, then, finally etc; and causal phrases (CP) such as: resulting in, making..., leaving me with, in order to, so. Student scores were compared both individually and as a whole group. Additionally, EL and Non-El student scores were examined and compared. A change in scores from pre- to post-intervention assessment indicates participants’ ability to use appropriate language structures to describe mathematical thinking. Additionally, self-evaluation questionnaire scores were aggregated and analyzed for trends which confirm or deny participant self-perceptions about the causal relationship between writing procedural recounts and their own conceptual understanding of how to solve algebraic equations in one variable.

**Reliability and Validity of Data**

The researcher scored all writing samples. To help ensure intrarater reliability, a copy of each writing sample was scored twice, on separate occasions and results from both data sets were analyzed for consistency. A color-coding system was used to identify the five language structures that were quantified. Where a discrepancy in an individual score occurred, that instance was reviewed a third time and determination of continuity was made to the final score. With respect to instrument reliability, each elicitation to explain how a problem was solved was made from an algebraic equation with similar degree of difficulty and complexity as determined by the math teacher. The reliability of the Self-Evaluation Questionnaire was strengthened with the use of a Likert scale upon which participants scored their relative usage and confidence/understanding on a scale
from 1-“No, not at all” to 5 “Yes, absolutely!” The questionnaire was read aloud and the scale was carefully described after each question to minimize confusion and ensure that responses conveyed the student’s intended response.

Ethics

This study employed several safeguards to protect participant’s rights. First, the details of the study, including the study’s objectives were described orally to participants who were then given an opportunity to ask questions. Details of the study were also communicated in written form and furnished to the parent/guardian in both English and the participants’ home language. Additionally, a copy of the study description was furnished to parent/guardian for their own record. The written permission of the participants’ parent/guardian as well as the participant was obtained and a copy of the permission statement was provided. Finally, all data collected for this study were kept confidential. Names were removed and copies were made from writing samples. All samples were coded with a numeric system and pseudonyms were assigned to the data to protect anonymity and allow for participant comparisons.

Conclusion

In this chapter, I described the quantitative and qualitative methods for this study. A description of the data collection techniques as well as the location, participants and materials was provided. Reliability, validity and protection of the rights of the student participants was also described. In the following chapter, I will present an analysis of the data that was collected in this classroom research study.
CHAPTER FOUR: RESULTS

This classroom research study took place in a co-taught standard eight math class during a five-week unit, which, among other standards, introduced solving algebraic equations in one variable. All 28 students in the class, including six non-ELs and 22 ELs, received a writing intervention by the ESL teacher and 10 of the students were participants in the data collection for this study. After being taught how to solve multi-step equations in one variable, students in this class were given a pre-intervention writing assessment in which they were to solve an equation and explain in writing how they solved the problem. Over the following weeks, the writing intervention took place in which the ESL teacher taught explicit lessons on how to write a procedural recount to explain their thinking processes while solving algebraic equations. During this process, participants practiced their writing skills in addition to their math skills and data was collected from a formative assessment. At the end of the unit, a summative assessment was given which contained a problem similar in difficulty to the pre-intervention assessment and explain their thinking process for solving the problem.

Quantitative language usage data was collected from the pre- and post-intervention. Additionally, qualitative data was collected using a self-reflection questionnaire in which perceptions about using procedural recounts to explain their thinking in math were measured on a Likert scale. The results of this study are presented in this chapter and organized by each data collection technique. This research study’s
questions are: After explicit instruction, do students choose language structures inherent to procedural recounts, such as technical verb processes, precise nouns, sequence words and causal phrases to describe their mathematical thinking? Additionally, do student self-perceptions of their mathematical abilities change after learning to write procedural recounts to describe their thinking processes?

In order to more fully interpret the tables in this chapter, a description of participants is provided, which gives an overview of participant status in terms of EL or Non-EL, native language, number of years in the US, number of years of formal education, Composite English Language Proficiency scores and Writing scores based on the WIDA ACCESS, and current Math Proficiency status based on the Minnesota Comprehensive Assessments (MCA) score. MCA scores are not available for students new to the country this year. Participant demographics data appears on Table 1 in chapter three.

**Pre-Intervention Results**

The first data collection technique consisted of a pre-intervention assessment in which students were given an algebraic equation with one variable to solve and then explain how they solved it. Responses varied, and only one of the 10 participants, a non-EL, chose to use words to help explain his thinking. The types of responses were organized into four categories: numbers; symbols, such as arrows or lines; charts; and math-specific nouns/noun phrases. Results are recorded on Table 2 below. Not surprisingly, participants used operational symbols as well as lines and arrows in a much higher frequency than words (math-specific nouns or noun phrases) on this assessment as numbers, symbols and charts were used by students up to this point in the curriculum
when orally describing how to solve such problems. Therefore, participants employed the use of the communication strategies they had thus far been taught. Only John, a non-EL, employed the use of math-specific nouns and noun phrases to help explain his thinking by describing these strategies with words. For example, he wrote “bags and coins” referring to a strategy used to understand the concept of terms and variables; and “S/U Chart” referring to a “sequence and undo” T-chart which notates the sequence of the equation down the left side of the chart and then “undoes” the sequence up the right side of the chart. This use of the math-specific noun phrases reflects John’s ability to label his work using the precise nouns and noun phrases he learned during the oral language stages of practice.

<table>
<thead>
<tr>
<th>Participant</th>
<th>Pre-intervention result</th>
<th>Correct solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abhir</td>
<td>Numbers, Symbols, Charts</td>
<td>Y</td>
</tr>
<tr>
<td>Hung</td>
<td>Numbers, Charts</td>
<td>Y</td>
</tr>
<tr>
<td>Taban</td>
<td>Numbers, Symbols, Charts</td>
<td>N</td>
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<tr>
<td>Jimena</td>
<td>Numbers, Symbols, Charts</td>
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<tr>
<td>Astur</td>
<td>Numbers, Symbols, Charts</td>
<td>Y</td>
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<td>Valeria</td>
<td>Numbers, Charts</td>
<td>Y</td>
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<td>Tahiiil</td>
<td>Numbers, Charts</td>
<td>Y</td>
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<tr>
<td>Julie</td>
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<td>N</td>
</tr>
<tr>
<td>Mary</td>
<td>Numbers, Symbols, Charts</td>
<td>Y</td>
</tr>
</tbody>
</table>
**Post-Intervention Results**

The second data collection technique consisted of quantifying the language usage instances from two separate writing samples in which participants were to solve an equation in one variable and explain how they solved it. While the number values from each of the algebraic equations used in this study were purposely varied, the complexity and degree of difficulty of the problems was kept consistent in order to increase reliability of the results. The first writing sample, labeled as “Formative,” was collected after two of the three explicit writing lessons; the second sample was collected from the unit summative assessment, labeled “Summative,” after the third explicit writing lesson. Whole group results appear on Table 3 below.

Participant written responses to the solving of an algebraic equation with one variable were analyzed and individual instances of the following five categories were tallied: Sequence Words (SW) such as first, next, then, finally, etc.; Causal Phrases (CP) such as: resulting in, making, leaving me with, in order to, so; Technical Verbs (TV) such as: use, apply, add, subtract, multiply, divide, remove; Common-Sense Verbs (CV) such as: did, get/got; and Math-Specific Nouns or noun phrases (MNP) such as: distributive property, x-terms, solution, chart, parentheses, equation. (Note, more than one instance of the same structure in a single sentence was counted as a single token; however, each use of the same structure in different sentences was counted as a separate token).

These five categories were further organized around two language structures identified by the WIDA writing standards frame work: Linguistic Complexity and Vocabulary Usage (see Appendix G for this writing rubric). “Linguistic Complexity” included use of sequencing words such as first, next, then, finally as well as causal
phrases such as *in order to, because, as a result, which left me with...* used to describe reasoning or justification. Vocabulary Usage included the use of technical math verbs such as the operations *add, subtract, multiply, divide, apply, remove, rearrange,* and “thinking” verbs such as *notice, evaluate.* In contrast to these technical verbs, “common-sense” verbs consisted of words used more commonly in oral language such as *get, got, did,* as in “*I did 2 and 4*” meaning “*I multiplied 2 and 4*” where the common-sense verb “*did*” is used instead of a the more technical verb “*multiplied.*” Vocabulary Usage also included the use of math-specific nouns and noun phrases such as *the distributive property, the left side of the equation, the x-terms.* Organizing the language features in this way made it possible to see participants’ usage along the continuum of English language development as measured and assessed by WIDA. The table below compares the results from the formative assessment and the summative assessment as a whole group. (For individual participant results, see Table 7 below).

<table>
<thead>
<tr>
<th>WIDA Writing Standard</th>
<th>Linguistic Complexity</th>
<th>Vocabulary Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formative</td>
<td>40</td>
<td>11</td>
</tr>
<tr>
<td>Summative</td>
<td>35</td>
<td>34</td>
</tr>
<tr>
<td>Percentage change</td>
<td>-12.50%</td>
<td>209%</td>
</tr>
</tbody>
</table>

General observations from the 10 participants’ (EL and non-EL) writing data with regard to Linguistic Complexity, which tallied the number of instances of sequencing
words and causal phrases, indicate the emergence of an inverse relationship. The sequencing words decreased by 12.5% from the formative assessment (40 instances) to the summative assessment (35 instances). Whereas, the use of causal phrases showed a marked increase of 209%, or from 11 instances in the formative to 34 instances in the summative.

Within the language structure of Vocabulary Usage, technical verb and common-sense verb usage were also inversely related: as the number of technical verb instances increased from the formative to the summative, common-sense verb instances decreased. The data show a gradual increase of technical verb usage of 3.7%, or from 54 to 56; and a gradual decrease from formative to summative of common-sense verbs, a change from 27 to 25, or -7.4%.

Also within the language structure of Vocabulary Usage, the use of math-specific noun phrases from the formative to the summative indicate a moderate increase of 23.9%, or from 46 instances in the formative to 57 instances in the summative. The use of math-specific noun phrases does not appear to be specifically related to any other category.

Finally, it is worth noting that both Taban and Julie, who did not solve the equation correctly in the formative, succeeded in solving the equation correctly on the summative.

**EL-only Results**

When the non-EL data is removed from the data sets, the language usage trends are similar to those mentioned above, with an exception within Vocabulary Usage (see Table 4 below). The technical verb usage decreased slightly from 34 in the formative assessment to 30 in the summative assessment, an 11.8% decrease, and the common-
sense verb usage increased slightly, from 18 in the formative assessment to 21 in the summative assessment, a 16.7% increase. This may be due to the fact that EL participants may have relied more heavily on the written model, which contained multiple instances of technical verbs and was available to them during the formative assessment. Notably, ELs relied more heavily on the common-sense, more familiar verbs such as “get” and “did” during the summative assessment and without the writing model. The number of instances of ELs' use of math-specific noun phrases increased by 25% from the formative to the summative assessment. There were 28 instances in the formative and 35 instances in the summative.

Within Linguistic Complexity, the EL-only data followed the same inverse relationship as the whole group. The use of sequencing words decreased slightly from 28 in the formative to 23 in the summative, or 17.9%. However, the use of causal phrases increased from 7 in the formative to 14 in the summative, representing a 100% increase. This inverse relationship may be due to the fact that as participants became proficient using causal phrases, they relied less on more rudimentary sequencing words to explain their mathematical thinking.

<table>
<thead>
<tr>
<th>WIDA Writing Standard</th>
<th>Linguistic Complexity</th>
<th>Vocabulary Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Category</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Formative</td>
<td>28</td>
<td>7</td>
</tr>
<tr>
<td>Summative</td>
<td>23</td>
<td>14</td>
</tr>
<tr>
<td><strong>Percentage change</strong></td>
<td>-17.90%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Individual EL results

A notable individual result came from Jimena, who was absent during the first data collection, but participated in the formative and summative assessments. While this participant was able to produce some writing on the formative with the use of the writing model, she was unable to either solve the mathematical equation correctly or put words to the process when working independently on the summative assessment. This participant’s composite ELP level on the WIDA ACCESS is 3.8/6 and the writing domain score is 3.2/6. According to the WIDA performance definitions for writing, Jimena is in the “Developing” category which means her Linguistic Complexity would be at the “Emerging” point, and Vocabulary Usage expectations would be the use of some specific content language. In addition, Jimena’s overall math proficiency as measured by the MCA standardized assessments is a “Does Not Meet” which may account for her overall challenge to succeed with the math and writing expectations of this study.

In general, participants with lower ELP levels showed weaker adherence to the overall trends. For example, with regard to Vocabulary Usage, Taban had very little change from formative to summative with the exception of the use of technical verbs. In this case, his usage of technical verbs dropped from five instances in the formative (with the writing model) to one instance when he had to produce the language independently. Taban was able to communicate the process and solve the equation successfully with the use of more common-sense words, for example “I did the Combining like-terms to find out this” and “I was doing the [insert chart drawing] like this.” While Taban could communicate the process of how he solved the equation, he continued to rely on the more familiar, common-sense words and drawing strategies. Similarly, with regard to
Linguistic Complexity, Taban’s use of sequencing words or causal phrases did not change from formative to summative. This could be due to his need to place a greater focus on solving the equations correctly. Taban’s composite ELP level is 3.8, which is supported by strong listening and speaking domains (6 and 4.7 respectively). His writing and reading domains are weaker (2.7 and 3.4 respectively). As an emerging writer, there is a reliance on the speaking form of communication to explain thinking.

Similar to Taban, Hung’s Vocabulary Usage dropped without the use of the writing model scaffold available during the formative assessment. Technical verb usage dropped from six instances to five and math-specific noun phrases dropped from five to four instances. Like Taban, Hung’s ELP composite score of 3.0 and her writing score of 2.8 indicate an emerging status as a writer.

The inverse relationship between sequencing word use and causal phrase use that surfaced in the aggregate data was evidenced individually by Abshir. Here, his writing also became more cohesive. For example, on the formative, he wrote:

“**First,** I noticed that there were parentheses so I used the Distributive property to get $3 + 8x + 10 + 5x = 94$. **Second,** I used commutative property **third,** I used the CLT [Combining Like Terms] to get $13x + 13 = 94$. **Fourth,** I used Additive property and **Finally,** I used Multiplicative property to get that $x = 6.23$.”

On the Summative writing sample, he wrote:

“**First,** I noticed the there were parentheses so I used the Distributive property to get $14x + 30 = 18 = 2x$. **Second,** I used the Additive property to join the x-term to get $12x + 30 = 18$ **third,** I used the S/U Chart to solve the equation so I used the
Additive property to get 12x-12, **finally** I used the multiplicative property and I got \( x = -1 \).”

In the first sample, there were five instances of sequence words (in bold) and one instance of causal phrase (underlined); in the second sample, the instances of sequence words dropped to four and the causal phrases increased to three. A close examination of the two samples reveals that the participant was able to link steps in the process of solving the equation by using the causal phrase “to solve the equation” which allowed him to continue through the solving process without having to specifically call out another step in the process with a sequence word. Both samples correctly lead to the solution, however the second sample is more cohesive and contains more lexical variety, whereas the first sample is more disconnected. Individual results with regard to Linguistic Complexity and Vocabulary Usage from the formative to the summative assessment is shown below on Table 5.
Table 5
*Formative Assessment Vs. Summative Individual Results (EL and Non-EL)*

<table>
<thead>
<tr>
<th></th>
<th>Linguistic Complexity</th>
<th>Vocab Usage</th>
<th>Math-specific Noun Phrase</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>correct answer</td>
<td>Sequencing Words</td>
<td>Causal Phrase</td>
</tr>
<tr>
<td></td>
<td>F S</td>
<td>F S</td>
<td>F S</td>
</tr>
<tr>
<td>Abshir</td>
<td>Y Y</td>
<td>5 4</td>
<td>1 3</td>
</tr>
<tr>
<td>Hung</td>
<td>Y Y</td>
<td>5 4</td>
<td>0 1</td>
</tr>
<tr>
<td>Taban</td>
<td>N Y</td>
<td>4 4</td>
<td>1 1</td>
</tr>
<tr>
<td>Jimena</td>
<td>N N</td>
<td>3 0</td>
<td>0 0</td>
</tr>
<tr>
<td>Astur</td>
<td>Y Y</td>
<td>4 5</td>
<td>2 4</td>
</tr>
<tr>
<td>Valeria</td>
<td>Y Y</td>
<td>2 3</td>
<td>1 3</td>
</tr>
<tr>
<td>Tahiil</td>
<td>N Y</td>
<td>5 3</td>
<td>2 2</td>
</tr>
<tr>
<td>Julie</td>
<td>N Y</td>
<td>3 6</td>
<td>2 7</td>
</tr>
<tr>
<td>Mary</td>
<td>Y Y</td>
<td>4 2</td>
<td>1 9</td>
</tr>
<tr>
<td>John</td>
<td>Y Y</td>
<td>5 4</td>
<td>1 4</td>
</tr>
<tr>
<td>Totals</td>
<td>60% 90%</td>
<td>40 35</td>
<td>11 34</td>
</tr>
</tbody>
</table>

Self-Evaluation Questionnaire Results

After receiving the results of their summative assessment, participants answered a close-ended self-evaluation questionnaire which was intended to address the second research question, “When students write procedural recounts to describe their mathematical thinking, does their perception of their own mathematical conceptual understanding increase?” A five-point Likert scale, (1=no, 2=very little/not much, 3=somewhat, 4=yes and 5=yes, very much!) was used so participants could reflect and answer on a relative basis. Participants answered five questions reflecting on their ability to describe their thinking in math before and after learning how to write a procedural recount and whether learning how to write procedural recounts in math affected their
understanding of the content and/or their confidence and conceptual understanding when solving algebraic equations. Whole group results were tabulated and presented in figure 3 below.

Figure 3: Self-evaluation questionnaire results – whole group.

**Whole Group Responses**

The whole group mean response to question 1, regarding the knowledge and use of math-specific words before intervention was 2.9, or just below *somewhat*, while the mean response after intervention (question 2) rose to 4.5 or between *yes* and *yes, very much*, an increase of 55.2%. The EL-only percent change was slightly lower at 43%. The non-EL percent change before and after rose 85.2% which may indicate that non ELs feel they benefit from explicit instruction in writing procedural recounts in math.

In response to participant confidence in the ability to explain answers in math before intervention (question 3), the whole group mean was 3.1, or just above *somewhat*. 
The group’s confidence level rose slightly after intervention to 3.8, or between *somewhat* and *yes*, an increase of 22.6%. Interestingly, the EL-only responses to participant confidence in the ability to explain answers in math before intervention compared to after intervention rose 37%, while the non-EL group confidence did not change before or after intervention. The whole group mean response to whether writing procedural recounts increased math understanding (question 5) was 3.6, or between “*somewhat*” and “*yes*.”

When EL-only and non-EL responses were separated from the whole group, there was very little change; 3.7 for EL-only and 3.4 for non-EL. Whole group mean responses appear below in Table 6.

<table>
<thead>
<tr>
<th>Table 6</th>
<th>Self-Evaluation Questionnaire Mean Score Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Question</td>
<td>Whole Group Mean Score</td>
</tr>
<tr>
<td>Before learning how to write a procedural recount, how much did you know about using precise math words to describe your thinking when solving equations in math?</td>
<td>2.9</td>
</tr>
<tr>
<td>After learning how to write a procedural recount, do you have a better understanding of how to use precise math words?</td>
<td>4.5</td>
</tr>
<tr>
<td>Percent Change before and after</td>
<td>55.20%</td>
</tr>
<tr>
<td>Before learning how to write a procedural recount, how confident were you about explaining your answers in math?</td>
<td>3.1</td>
</tr>
<tr>
<td>After learning how to write a procedural recount, how confident are you about explaining your answers in math?</td>
<td>3.8</td>
</tr>
<tr>
<td>Percent Change before and after</td>
<td>22.60%</td>
</tr>
</tbody>
</table>
Individual Participant Responses

The self-evaluation questionnaire results were tabulated individually and compared to whether or not the equation was solved correctly. There was a strong correlation between a positive perception that learning to write procedural recounts deepened math understanding and a correct solution on the math assessment. Participants who identified themselves as a 4 (yes) or a 5 (yes, very much) in answer to the question “Do you feel that learning how to write a procedural recount to explain your answers in math helps you understand the math better?” correlated with a correct solution. Conversely, Jimena perceived that learning procedural recounts did not affect her math content understanding and she was also unable to solve the equation correctly.

In order to take the analysis one step further, individual responses to question five from the self-evaluation were compared to the participant’s ability to correctly solve the equation in the formative and the summative assessments. This comparison appears below on table 7.
Table 7
*Formative/Summative Math results Vs. Self-Evaluation Response #5*

<table>
<thead>
<tr>
<th>Participant</th>
<th>Correct solution Formative</th>
<th>Correct solution Summative</th>
<th>Self-Evaluation response #5</th>
<th>Improvement present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abshir</td>
<td>Y</td>
<td>Y</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Hung</td>
<td>Y</td>
<td>Y</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Taban</td>
<td>N</td>
<td>Y</td>
<td>5</td>
<td>Yes</td>
</tr>
<tr>
<td>Jimena</td>
<td>N</td>
<td>N</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Astur</td>
<td>Y</td>
<td>Y</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Valeria</td>
<td>Y</td>
<td>Y</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Tahiil</td>
<td>N</td>
<td>Y</td>
<td>4</td>
<td>Yes</td>
</tr>
<tr>
<td>Julie</td>
<td>N</td>
<td>Y</td>
<td>3</td>
<td>Yes</td>
</tr>
<tr>
<td>Mary</td>
<td>Y</td>
<td>Y</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>John</td>
<td>Y</td>
<td>Y</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

Table 7 draws attention to Taban, Tahiil and Julie who did not solve the equation correctly on the formative but did solve it correctly on the summative, showing a possible growth in math conceptual understanding. Taban and Tahiil, who are both ELs, responded *yes-very much!* to the question about whether learning to write procedural recounts to explain his answers in math helps him understand the math better. Julie, a non-EL, responded *somewhat* to the same question.

**Summary**

In this chapter, the results of this study were presented and analyzed. In Chapter Five, patterns that the data reveal will be discussed, as well as implications for ESL
teachers, math teachers, students and school administration. Additionally, limitations of the study and further areas of study will be explored.
CHAPTER FIVE: CONCLUSION

This research study sought to answer two questions: After explicit instruction, do students choose language structures inherent to procedural recounts, such as technical verb processes, precise nouns, sequence words and causal phrases to describe their mathematical thinking? Additionally, do student self-perceptions of their mathematical abilities change after learning to write procedural recounts to describe their thinking processes? A classroom research study was designed in which 8th grade student EL and non-EL participants were explicitly taught a writing genre called a procedural recount in order to give them skills in choosing language to describe their mathematical thinking processes. Pre- and post-intervention language structure data was collected and analyzed. A self-reflection questionnaire was used to gain insight into the second question. This chapter is a review of the major findings of this study and its implications for students, teachers, and administrators. A discussion about its limitations and suggestions for further research are also included.

Major Findings and Implications

Pre-intervention data

The pre-intervention quantitative data confirmed the research of de Oliveira and Cheng (2011) and Schleppegrell (2007) regarding the challenges that the multi-semiotic nature of math language presents to students, especially ELs, as they cross-reference and shift between the symbols used in math and the language used to express the meaning
and operations of math symbols. Without the knowledge of a writing structure such as a procedural recount, students struggle to communicate their mathematical processes with written language.

The results of this study also corroborated the researcher’s general observations that when students were faced with an elicitation to explain how they solved an algebraic equation in math, they rarely chose language to describe the process, but instead relied on numbers, symbols and graphic tools. The results showed that in only one case, a non-EL participant produced a few instances of math-specific noun phrases to describe his thinking, though these noun phrases occurred in the data as a label to name the step in his work rather than as a precise noun phrase within a written explanation. Since participants had been taught how to solve the algebraic equations prior to the pre-intervention writing assessment, only those strategies which had been learned, such as drawing arrows or creating T-charts were used when trying to explain how they solved the problem. Thus, while most of the EL participants in this study were able to show their work using the semiotic systems of math, there was no evidence of an ability to explain or justify their thinking using a procedural recount.

This finding underscores the importance for explicitly teaching those skills which are needed to accomplish the task of explaining thinking processes when solving math problems. If a math curriculum expects students to perform this writing task, based on the belief that the ability to explain one’s thinking actually increases student understanding of the concept, then students, especially ELs, must be taught the discreet skills to do so (Moschkovitch, 1999; Schleppegrell, 2007).
Post-intervention Data-Linguistic Complexity

The subsequent data collection writing samples taken from the formative and the summative assessments showed evidence of increased use of the language structures of a procedural recount to explain thinking processes in math. There were two notable findings in the aggregate data. The first was in regard to Linguistic Complexity. Participant use of causal phrases such as in order to or which left me with, increased markedly while the use of sequence words such as first, second, next, after that, decreased. One possible reason for this inverse relationship is that as participants grew more proficient with the use of causal phrases to demonstrate thinking processes, the need to explicitly identify each step in the process diminished. In other words, causal phrases both helped to explain or imply how or why a step is taken in solving an equation, offering more information to the reader about the individual’s thinking processes as well as decreasing the need to call attention to that process with a sequencing word.

Additionally, the use of causal phrases increases the overall complexity of the text and has the effect of making the writing more cohesive and readable and less formulaic. This finding follows what Fang and Schleppegrell (2008) and Humphrey et al. (2012) imply in their research regarding procedural recounts. In general, when language structures specific to a writing genre are explicitly identified and taught, students have access to the language which not only increases the level of complexity, cohesiveness and readability of the writing, but also allows the writer to convey a deeper understanding of a mathematical concept, which, in this case is making cause and effect connections.
Vocabulary Usage

The second notable finding in the aggregate data appeared within the category of Vocabulary Usage. Here, an inverse relationship was found between the use of technical verbs and common-sense verbs. It appeared that as participants increased the use of technical verbs, the dependence on common-sense verbs decreased. This might be due to the multiple opportunities to practice using technical verbs during classroom discourse and peer editing activities, which, as Barwell (2005) and Schleppegrell (2007) claim, is necessary in order to fully comprehend the meaning of technical math terms. Another possible reason for this drop in common-sense verb usage could be the attention paid to differences between using oral language to explain a process compared to writing procedural recounts. In fact, as participants engaged in peer-editing writing samples, they were tasked with identifying when a technical verb such as *applied* could take the place of a common-sense verb such as *did*, or when the technical verb phrase *which left me with* could take the place of *to get*. This activity may have increased participants’ awareness of how writing requires a more accurate and precise language usage compared to speaking, which is generally less formal and uses gestures, symbols or other forms of communication in place of words. This may point to how the meta-cognitive awareness of the language structures typical of a procedural recount increases the student’s ability to choose words when writing to explain thinking processes, whether in math or in other content areas.

Interestingly, when EL data was separated from the whole-group results, the inverse relationship between technical verb use and common-sense verb use disappeared. In fact, from the formative to the summative assessment, common-sense verb usage
actually increased within the EL subset. This may be due to an increased reliance by ELs on the writing model during the formative assessment. When the model is taken away, ELs may more easily revert to more common and familiar words. The implications of this finding for ESL teachers and math teachers are to acknowledge that EL students may require more supports and for a longer period of time to allow for more time to practice these language structures.

**Self-Reflection Questionnaire Data**

The qualitative data collected from the self-reflection questionnaire suggested a possible correlation between participant self-perception about whether writing a procedural recount contributed to their ability to understand the math concepts and their ability to successfully solve the algebraic equations. Participants who believed their understanding of the math concept was deepened through learning to write procedural recounts were also able to successfully solve the equation. On the other hand, Jimena reported that learning to write a procedural recount had little or no effect on her understanding of the math concept, and she was also not able to successfully solve the equation. There are multiple ways to interpret this correlation. It could be that when a participant struggles initially to understand the concepts behind how to solve an equation (for example, how or why the distributive property is applied) the struggle persists when an explanation about how they solved it is requested. For example, some participants were able to articulate a justification for why they applied the distributive property to the equation: *in order to remove the parentheses*. This kind of justification demonstrates a conceptual understanding of when and how to use this property of mathematics.

According to Fang and Schleppegrell (2008) and Humphrey et al. (2012), a procedural
recount provides a framework for connecting ideas around practical learning experiences; however, if the practical learning has not taken place, then perhaps the recount is less meaningful.

Another interesting finding from the self-evaluation questionnaire came from the responses to whether or not learning to write procedural recounts increased confidence levels in explaining mathematical thought processes. The mean score for the EL participants rose 32% whereas the non-EL participant confidence level grew 14.6%. The fact that the EL participants felt a greater increase in confidence may not be surprising since ELs may generally feel less confident about speaking or writing in an academic English setting than non-ELs. However, the increase in confidence to explain mathematical thinking for this group may imply that learning to write a procedural recount could have an overall positive affect on EL confidence in participation in the mathematics classroom. This corroborates Hansen-Thomas’ (2009) findings where students who were successful in math generally spoke more in class; verbalizing solutions, offering rationale, evaluating and questioning during classroom discourse.

**Limitations**

There are a number of limitations to this study. Because this was designed as a classroom research study in a naturalistic setting, the study was subject to the timing of a curricular unit, working around school schedules, teaching schedules and participant absences. As such, we focused the study within one math curricular unit and on one discreet math skill: solving algebraic equations in one variable. This limited the amount of time over which the study could take place. The time period allowed for only three explicit writing lessons to be taught. Additionally, the amount of time for participants to
practice the new skill of writing procedural recounts was limited. This study could be strengthened through extension over a longer time-frame to get a better sense of whether the use of the language structures persists over time and whether the growth and inverse trends continue over time.

The small number of participants was also a limitation of this study. With only 10 data points, it is difficult to draw any meaningful conclusions. Low participation rate was a risk to the study as the class had a total of only 28 students. Additionally, the study relies on some knowledge of math aptitude yet it is difficult to ascertain the effects of math aptitude and language aptitude.

**Implications**

This study holds important implications for several groups including participants, ESL teachers, secondary mainstream content teachers and school administrators. The self-evaluation data gives participants information about how increasing writing skills contributes to their conceptual learning of math as well as their confidence in explaining their mathematical thinking. It may provide motivation to students to apply themselves when given writing tasks as well as an understanding about how a writing genre has specific elements that can be used as tools to apply in other content areas. I plan to share the results of this study with my students so that they can have an opportunity to reflect on the connections between writing and math. Both ESL and content-area teachers may be interested in the findings about increased confidence levels and conceptual understanding in ELs when explicitly taught the language structures used to explain their thinking processes.
ESL teachers may benefit from the findings which support writing in the content area of math and the positive effects that could occur with regard to increasing EL students’ awareness and use of technical verbs, math-specific nouns and noun phrases as well as sequencing and causal structural language used in procedural recounts. The writing genre of procedural recounts could be used across disciplines such as science or technology and contribute positively to the necessary development of writing skills for ELs. ESL and content-area teachers may benefit by examining the writing lessons and modified assessments in Appendix B and E. These examples may help garner ideas for supporting secondary emerging language learners as well as all students’ language development in the mainstream classroom. Finally, secondary school administrators may find evidence in this study to support a co-teaching model in mathematics, as well as explicit language instruction in the mainstream classrooms, due to the positive effects of this instruction on academic language development for both EL and non-EL students.

Results of this study will be shared with the administration and ESL teaching staff in my district to help inform and guide instructional models for our EL programming. Additionally, my colleagues in the math department will be able to use the data and research provided in this study to identify more opportunities to incorporate writing into our math curriculum.

Further Research

One question that arose during the analysis of this research study was: does writing help solidify conceptual understanding or does conceptual understanding allow for the ability to give a written explanation? I would like to know more about struggling math learners like Jimena whose composite ELP of 3.8 and a writing score of 3.2 would
indicate much stronger writing skills than she was able to produce in this study. There are other ELs who fall into this category but were not participants in this study. It would be helpful to focus a similar study on ELs with similar ELP and background as Jimena because, according to the research, this demographic is most at-risk for not graduating from high school and it is imperative that we find a pedagogical approach for these students to fortify them with the skills to succeed in high school and beyond.

**Personal Reflection**

Conducting this research study gave me a new appreciation for the time and effort that goes into quality research in the field of ESL. As a result, I have become a better consumer of research, paying closer attention to procedures, research questions, and the limitations inherent to the research process. I also gained a stronger appreciation for data collection, not only within the confines of conducting a research study, but also as a practitioner; data is an important tool in identifying learning trends as well as the effectiveness of pedagogical strategies.

Conducting this research study also sharpened my skills as an ESL teacher and as an advocate for ELs. Throughout this project, I found new resources in the field of SFL and learned to more keenly identify the language structures specific to mathematics that present unique challenges to ELs. I believe I can take this knowledge across other curricular areas, applying my growing understanding of SFL theory and text analysis. I have compiled a robust reference list of research studies and SFL theorists to which I will refer as I continue to co-teach across multiple disciplines. While my research may make only a very small contribution to the body of research around teaching ELs, I am proud to
contribute anything at all, and perhaps most valuable for me are all the questions that remain unanswered.
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Appendix A: Pre- and Post-Intervention Assessments

Pre-intervention formative assessment:

Name ____________________________________________

Solve for x: \[ 3(2x + 12) = 24 + 4x \]

Explain:
Post-intervention formative assessment:

Solve the following equations and write out in WORDS what you did and why.

1) \(2(4x + 6) = 36\)

**Example:** First, I noticed that there were parentheses, so I used the Distributive Property to get \(8x + 12 = 36\). Second, I used the Additive Property and subtracted 12 from 36. This left me with \(8x = 24\). Lastly, I used the Multiplicative Property and I divided 24 by 8, make in \(x = 3\).

2) \(3x + 8 + 2x + 2 = 60\)

Post-intervention summative assessment:

Solve the following equations. Circle one and describe how you solved it using full sentences and precise mathematical language. Be sure to mention which properties you used.

b. \(2(7x +15) = 18 + 2x\)
Appendix B : Procedural Recount Writing Lesson Plan Outline

Day 1: Introduction

Language Development Objective: SWBAT identify orally some words we use in everyday language to describe sequencing a procedure/how to do something.

Ask: Why do you think the math tests ask you to “explain” your thinking?

Think/pair/share: Find an example when you have to explain your thinking to a friend/sibling/parent (to justify an action; to make something; cooking). What helps you explain how to do something?

Demonstrate: choose a volunteer to describe to me how to send a text (start with my phone completely off; student may forget to tell me to turn my phone “on” which draws attention to details when recounting a procedure.

Write in notebooks: What words do we use to describe our thinking in math?

Day 2: Model and practice Procedural Recount

Language Development Objective: SWBAT create lists of technical verbs and math-specific nouns used to describe how to solve an equation and write a procedural recount.

Warm-up: (solve an equation on the whiteboard) ask for volunteer to show us how they solved it. I will dictate the student’s description of how to solve the problem, modeling on the whiteboard. Underline/circle all the technical words that student used to describe how to solve the problem (sequencing words, any math-specific nouns/technical verbs)
**Math Writing activity:** Using the model at the top of the worksheet, students solve four similar equations and describe their process for solving each one. Students work alone or with a partner to solve and write. Students hand in the worksheet at the end of class.

**Day 3: Peer-Editing Procedural Recount**

**Language Development Objective:** SWBAT identify sequence words and causal phrases on a partner’s procedural recount.

**Warm-up:** A model of a Procedural recount is projected. Students list all the technical verbs and math-specific nouns that appear in the model. Students list other words that help explain the procedure (sequencing words and causal phrases).

On poster paper, I write words that students identify and we create posters for the wall.

**Activity:** Project student examples of their writing from the procedural recount worksheet. Find examples which highlight everyday language and as a class, we “edit” the writing to make it more like a procedural recount. Examples: students start sentences with “So, first you need to times the 3 and the 7” As a class, we discuss how to write more clearly and with technical verbs and math-specific nouns. “First, apply the distributive property and multiply the x-terms in order to remove the parentheses.” Show students the peer editing checklist, structure of a procedural recount worksheet and rubric for writing levels.

**Peer-editing Activity:** with a partner, students use the peer-editing checklist to edit one another’s writing from the worksheet from lesson 2. Students re-write their procedural
recount onto the worksheet using the language and the structure of a procedural recount.

Students hand in the new draft.
Appendix C: Participant-generated Classroom Wall Posters

Technical Math Verbs (TV):

*add, subtract, multiply, divide, apply, remove, combine, re-arrange, notice, evaluate, solve*

Math-specific Nouns

*equation, distributive property, additive property, multiplicative property, commutative property, like-terms, x-terms, parentheses, the left/right side of the equation*

Sequencing Words, Math-specific Noun Phrases/Causal Phrases:

*“I used the distributive property in order to remove the parentheses.”*

First, I multiply the coefficient by each term in the parentheses. Then, I add the products together and I get ______________.

*“I used the commutative property to re-arrange the x-terms.”*

(Posters were color-coded to bring attention to all language structures being used.)
Appendix D: Peer-editing Checklist

Peer Editing Practice Names: ___________ and ___________

☐ Does the writer use sequencing words to clarify the steps? Circle the sequencing words…

☐ Does the writer use “math” verbs (like “I subtracted” rather than “I did 4 - 2.” )

☐ Does the writer justify the steps? (so that…in order to…)

☐ Does the writer use a variety of words? (underline words that repeat, can you suggest other words to use?)

☐ Does the writer use precise math words? (Can you suggest precise words to use?)

☐ Tell the writer something that they did well.
**Appendix E: EL Math Writing Scaffolds and Modified Assessments**

**Math Writing Scaffold**

**Math Writing - Procedural Recount “Explain your thinking” Here’s what I did and Why:**

<table>
<thead>
<tr>
<th>Procedural Recount</th>
<th>Solving Equations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Orientation:</strong></td>
<td><strong>Problem:</strong></td>
</tr>
<tr>
<td>(Topic sentence) state your answer to the problem. My answer is ...</td>
<td></td>
</tr>
<tr>
<td><strong>Sequential details:</strong></td>
<td><strong>Justifying steps (Ex. so, in order to, resulting in...) My answer makes sense because...</strong></td>
</tr>
<tr>
<td>- First, then, next, firstly...</td>
<td></td>
</tr>
<tr>
<td>- Thinking and Doing Verbs: (Ex. I noticed... I applied the... I simplified... I multiplied...)</td>
<td></td>
</tr>
<tr>
<td>- Noun phrase/Precise Descriptions: (Ex. ready to solve, equation, distributive property...)</td>
<td></td>
</tr>
<tr>
<td><strong>Evaluation/Judgement:</strong></td>
<td><strong>Language of a Procedural Recount:</strong></td>
</tr>
<tr>
<td>(Concluding sentence)</td>
<td><strong>Level 1-2</strong></td>
</tr>
<tr>
<td>Justifying steps (Ex. so, in order to, resulting in...) My answer makes sense because...</td>
<td>- Label steps with math terms</td>
</tr>
<tr>
<td></td>
<td>- Draw diagram to show understanding</td>
</tr>
<tr>
<td></td>
<td>- Use sentence frames</td>
</tr>
<tr>
<td><strong>Level 3-4</strong></td>
<td>- Write longer sentences with some details</td>
</tr>
<tr>
<td></td>
<td>- Usually use correct sentence structure</td>
</tr>
<tr>
<td></td>
<td>- Use some math verbs and specific math terms</td>
</tr>
<tr>
<td></td>
<td>- Use sequence words and causal phrases</td>
</tr>
<tr>
<td><strong>Level 5-6</strong></td>
<td>- Use variety of ways to express meaning (actions and results)</td>
</tr>
<tr>
<td></td>
<td>- Use precise math words; avoids general words</td>
</tr>
<tr>
<td></td>
<td>- Use variety of language (sequencing/causal phrases to organize and convey explanation.)</td>
</tr>
</tbody>
</table>
Modified Summative Assessment - EL Level 1-2

Name: _______________________

Word Bank:

<table>
<thead>
<tr>
<th>Commutative Property</th>
<th>Distributive Property</th>
<th>Combining like-terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Additive Property of Equality</td>
<td>Multiplicative Property of Equality</td>
<td></td>
</tr>
</tbody>
</table>

Solve the equations and complete the sentences below.

\[ 4 + 2(3x + 2) = 32 \]

First, I use the __________________ property.
Then, I use the __________________ property.
Next, I use the __________________ property.
After that, I use the __________________ property.
Finally, I use the __________________ property.
Making \( x \) equal __________.

\[ 7x + 3(5 + 2x) = 45 \]

First, I use the __________________ property.
Then, I use the __________________ property.
Next, I use the __________________ property.
After that, I use the __________________ property.
Finally, I use the __________________ property.
Making \( x \) equal __________.
Appendix F: Self-Evaluation Questionnaire

Student Self-Evaluation

Name ________________________________

Please circle a number to answer the following questions about writing a procedural recount to "describe your thinking" in math.

On a scale of 1-5 (1=no, 2=very little/not much, 3=somewhat 4=yes 5=yes, very much!)

| Before learning how to write a procedural recount, how much did you know about using precise math words to describe your thinking when solving equations in math? | 1 | 2 | 3 | 4 | 5 |
| After learning how to write a procedural recount, do you have a better understanding of how to use precise math words? | 1 | 2 | 3 | 4 | 5 |
| Before learning how to write a procedural recount, how confident were you about explaining your answers in math? | 1 | 2 | 3 | 4 | 5 |
| After learning how to write a procedural recount, how confident are you about explaining your answers in math? | 1 | 2 | 3 | 4 | 5 |
| Do you feel that learning how to write a procedural recount to explain your answers in math helps you understand the math better? | 1 | 2 | 3 | 4 | 5 |
## Appendix G: Math Writing Rubric - Procedural Recounts

Math Writing Rubric: Procedural Recounts

<table>
<thead>
<tr>
<th></th>
<th>Level 1-2</th>
<th>Level 3-4</th>
<th>Level 5-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linguistic Complexity</td>
<td>Use one word or a memorized chunk, label steps in a process, use sentence frame <em>Ex. First, I use the _____ property</em></td>
<td>Use some sequencing words and causal phrases <em>Ex. First, I did ... because...</em></td>
<td>Use variety of language (sequencing / causal phrases) to organize and convey explanation <em>Ex. First, I noticed... so I applied... in order to...etc</em></td>
</tr>
<tr>
<td>Vocabulary Usage</td>
<td>Use only most common words, use technical words from a word bank</td>
<td>Use some math-specific words, use some technical verbs</td>
<td>Use math specific nouns/ noun phrases, use technical verbs, avoids overuse of common sense verbs (<em>did, got</em>)</td>
</tr>
</tbody>
</table>