Culturally and Linguistically Responsive Mathematics Word Problem Solving with English Learners

A DISSERTATION
SUBMITTED TO THE FACULTY OF THE
UNIVERSITY OF MINNESOTA
BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY

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December 2019

Acknowledgements

I would like to offer acknowledgement and gratitude to the advisers and mentors who helped throughout the completion of this dissertation, and graduate school in general. First, I would like to thank my adviser Dr. Robin Codding. I am grateful for her guidance and for sharing not only her expertise but also her passion and excitement for the research of mathematics interventions. Second, I would also like to acknowledge my co-adviser, Dr. Amanda Sullivan, who set high expectations for my work throughout graduate school and made me a better writer, researcher, and school psychologist because of it. I would also like to offer thanks to Dr. Jennifer McComas for her support as my committee chair and also for her natural ability to create invaluable professional connections. Thanks to Dr. McComas I have had opportunities which significantly furthered my professional career and created relationships that have greatly benefitted my research and practice. In addition, I would like to thank my committee member Dr. Kendall King for her support and valuable insight on the instruction of English learners. Finally, I would like to offer a heart-felt thank you to Dr. Annie Hansen-Burke for her steadfast support throughout graduate school. Dr. Hansen-Burke has inspired a love for the field of school psychology and helped foster a program climate that made my graduate school education enjoyable and meaningful.

I would also like to acknowledge my friends and colleagues who have supported me. Thank you to Mohammed Almalki and Alaa Houri, my volunteer interventionists, who made conducting this intervention possible while completing my internship year. Huge thanks also go to my entire graduate school cohort who became good friends; I believe our group dynamic was truly unique and created a supportive environment in which we all flourished.

I also recognize the time and support of the educators and students who participated in this study. The students are what made this project meaningful and representing their growth as data on a page does not capture the pride I felt in their accomplishments.

Finally, I would like to thank my wonderful family. Thank you to my mom and very first editor, Chris Jones. Thank you for teaching me how to write, how to be a good person, and how to pursue my dreams. Thank you also to my dad and step-mom, Charlie and Betsy Jones, for their unyielding support and for believing in me even when I doubted myself. Lastly and most emphatically, thank you to my fiancé Erik Warren for everything. He is my greatest cheerleader and I can’t imagine where I would be on this journey without him.

Abstract

Schema-based instruction is recognized as an effective practice to teach children word problem solving skills. The purpose of this study was to evaluate the effectiveness of a culturally and linguistically responsive adaptation to schema-based instruction with a sample of Spanish-speaking English learners. A multiple probe design across participants was used to evaluate the efficacy of the culturally and linguistically responsive schema-based instruction on word problem solving performance. Maintenance of intervention effects was assessed six weeks following intervention implementation. Student perceptions of the culturally and linguistically responsive schema-based intervention were also measured. Results indicate that the intervention was successful at improving and maintaining word problem solving performance with this sample. The students reported an overall positive attitude toward the intervention, providing evidence that they understood, enjoyed, and felt they benefited from the intervention.

Keywords: Mathematics, intervention, English learners, schema-based instruction

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CHAPTER 1

Introduction

The mathematics achievement gap between English learners (ELs) and their native English-speaking peers is a persistent concern in educational research and policy as documented by results from the National Assessment of Educational Progress (NAEP; National Center for Educations Statistics [NCES], 2019). Historically, limited English proficiency is treated as a literacy problem, with less focus on students' mathematics achievement (Baker et al., 2014); however the mathematics achievement gap illustrates an equally concerning problem given the important life outcomes related to math achievement (e.g., Duncan & Murnane, 2011). The Every Student Succeeds Act (ESSA, 2015) mandates educators use evidence-based practices with students who are struggling and prioritizes the need for all students, including ELs, to meet accountability goals. Word problem solving specifically poses unique challenges to ELs because of the added burden of language comprehension (Martinello, 2008). This study seeks to add to the literature by examining a potential solution to bolster EL students' performance on word problem solving tasks. An evidence-based mathematics word problem solving intervention, schema-based instruction (SBI), was adapted to incorporate culturally and linguistically responsive pedagogies. This culturally and linguistically responsive SBI (CLR-SBI) was evaluated for its efficacy in supporting math word problem solving of ELs.

Background

Mathematics is an increasingly important area in education research due to the short- and long-term outcomes associated with mathematics proficiency. Students with low mathematics skills fall increasingly behind in math over time (Morgan, Farkas, & Wu, 2011). As students get older, persistent problems in math are associated with lower high school graduation rates (Duncan & Murnane, 2011) and students who take more math courses, especially higher-level math courses, have higher earnings as adults (Rose & Betts, 2004). This evidence suggests math achievement has significant impacts on students' lives in education and beyond.

Given the importance of math and the low overall achievement of students in math across the U.S. (NCES, 2019), the Common Core State Standards Initiative (CCSSI) developed standards for U.S. students in math (National Governors Association Center for Best Practices & Council of Chief State School Officers [NGA Center & CCSSO], 2010). While the increasing attention and standards in math is promising, many subgroups of students still fail to achieve grade level proficiency in math. NAEP data indicates that 84% and 94% of fourth and eighth-grade ELs, respectively, scored below proficient in mathematics compared to 56% and 64% of fourth and eighth grade non-ELs, respectively (NCES, 2019).

These statistics are alarming considering that the proportion of ELs in U.S. schools is rising. The number of EL students in U.S. schools has grown by 52.3% between the years of 1998 to 2008 (Batalova & McHugh, 2010). Recent statistics show that 9.1% of public-school students are ELs, and in large cities this proportion increases to 16.7% of students (Snyder, de Bray, & Dillow, 2017). Of these students, 70% are Spanish-speaking (Fry & Passel, 2009), but there is also substantial diversity in languages spoken, socioeconomic status, academic literacy in their first language, family and trauma history, and exposure to educational systems, among many other relevant aspects (LaCelle-Peterson & Rivera, 1994).

The achievement gap for ELs may be partly attributed to the strong connection between language proficiency and math achievement (Abedi & Lord, 2001) as indicated by recent research showing when reading achievement is controlled for, there is little to no significant difference between the math performance of ELs and non-EL students (Chen & Callhoub-Deville, 2016). Another hypothesis is that the limits of working memory drive the difficulties ELs have in the math classroom because they are simultaneously translating the language of instruction as they attempt to understand the math content (Bumgarner, Martin, & Brooks-Gunn, 2013). It has also been proposed that ELs are simultaneously learning two languages in the math classroom: English and the language of mathematics (Baker et al., 2014).

Word problem solving is emphasized as an important skill throughout all domains of mathematics and is one of the first ways in which young children begin to develop proficiency with whole numbers (National Mathematics Advisory Panel, 2008; National Research Council, 2001). However, word problems quickly become more complex and for older students represent more complex problem-solving situations. By the time students are given the NAEP assessments in fourth grade, performance on word problem solving is already weak and it does not improve on future assessments in the eighth and twelfth grades (National Research Council, 2001). Fourth graders are much more likely to answer an arithmetic question correctly when presented numerically than when the same numbers are presented in a word problem, demonstrating the challenge these problems pose for students (Silver, Alacaci, & Stylianou, 2000).

Solving word problems is a challenging task for many students, but ELs face the additional barrier of solving them in their non-native language. Research from around the world has shown that bilingual students do not perform as well on word problems in their second language (L2) as monolingual students (e.g., Kempert, Saalback, & Hardy, 2011). Research has also shown that some bilingual students perform better on word problems stated in their first language (L1) than their L2 (e.g., Bernardo & Calleja, 2005). Linguistic factors such as unfamiliar academic vocabulary and syntax may contribute to the difficulties ELs encounter with word problems (Ambrose & Molina, 2014). Previous research on how best to instruct and intervene with ELs in mathematics is particularly limited (Jones, 2017), and few studies have examined how to support ELs' word problem solving performance (e.g., Orosco, 2014). In a systematic review of math instruction and intervention strategies for use with ELs, only seven studies out of seventeen studies investigated word problem solving specifically (Jones, 2017). Given these factors this paper seeks to investigate a potential word problem solving intervention designed specifically for EL students.

Schema-Based Instruction

Educators must take steps to ensure that ELs are supported in the content areas, including mathematics. However, due to the limited research available on teaching mathematics to ELs, educators may find it difficult to know how to do so. Word problem solving is an area of increased importance for ELs due to the naturally high linguistic demand involved and because of their high prevalence on high stakes assessments. Previous research has shown evidence that a culturally and linguistically responsive schema intervention (CLR-SI) can improve the word problem solving performance of

ELs (Driver & Powell, 2017). Schema intervention is an umbrella term used to describe interventions that utilize strategy instruction to prime the underlying problem structure of word problems. Three independent groups of researchers have investigated the efficacy of this approach (e.g., Fuchs et al., 2014; Jitendra et al., 2013; Xin & Zhang, 2009). This study seeks to expand the work done by Driver and Powell (2017) on a culturally and linguistically responsive schema intervention using the specific approach developed by Jitendra and colleagues, schema-based instruction (SBI; Jitendra & Hoff, 1996).

Schema-based instruction (SBI) has been shown to be effective at improving word problem solving performance of native English-speaking students with and without math difficulties (MD; Jitendra & Hoff, 1996; Powell, 2011). SBI incorporates explicit instruction to teach students to recognize a problem's schema, implement a diagram based on that schema, and then solve the problem (Jitendra et al., 2013). SBI is based on schema theories from cognitive psychology, research on expert problem solvers, and research on instructional practices for students at risk for MD (Jitendra et al., 2013). Schema theories emphasize the importance of understanding semantic structure in order to comprehend and solve word problems (Sweller, Chandler, Tierney, & Cooper, 1990). Research on expert problem solvers has shown that they can distinguish between relevant and irrelevant information, use knowledge of problem-solving procedures for different types of problems, and have strong metacognitive skills (Van Dooren, de Bock, Vleugels, & Verschaffel, 2010). Research on students with MD has identified key components of instruction for word problem solving that are incorporated into SBI including visual representations of schemas, explicit instruction of problem-solving heuristics, and instruction of metacognitive strategy knowledge (Jitendra et al., 2013).

Several schema intervention studies have included EL students in their sample populations (e.g., Jitendra et al, 2013) but few have reported effects separately for these students. Jitendra and colleagues (2007) reported the performance of EL students together with students with disabilities and students receiving Title I math services and separated their outcomes from the full sample. This sample showed improved word problem-solving performance on maintenance probes administered six weeks after intervention in comparison to the control group (Jitendra, Griffin, Haria, Leh, Adams, & Kaduvettoor, 2007). Fuchs and colleagues included English as a Second Language (ESL) status as a covariate in their investigation of the relative effectiveness of a schema intervention and a calculation intervention, but did not find any interaction effects between ESL status and treatment condition (Fuchs et al., 2014).

Finally Driver and Powell (2017) explicitly investigated the impacts of a culturally and linguistically responsive schema intervention (CLR-SI) on the word problem solving performance of nine ELs using a quasi-experimental approach. Adaptations were made to the traditional schema intervention approach to make it responsive to ELs including explicit measurable lesson objectives, facilitated oral discussions with students, permitted native language use, graphic organizers and manipulatives, incorporation of students' own ideas and experiences, and culturally relevant instructional examples. The performance of the sample in this study was compared with a representative sample of students comprised of 16% ELs whose data were collected over multiple years. Their results suggest that the EL sample in their study moved from being "at-risk" (as defined by the 25th percentile on a brief word problem solving assessment) in comparison to the normative sample, to performing similar to students without math difficulties following the implementation of CLR-SI. These results suggest that a schema intervention is a promising approach to improve the word problem solving performance of ELs that warrants further attention.

Culturally and Linguistically Responsive Practices

As in the preliminary study by Driver and Powell (2017), this study seeks to investigate the efficacy of incorporating culturally and linguistically responsive (CLR) approaches to a schema intervention targeting word problem solving. The purpose of this approach is to improve the academic performance of a historically underachieving population of students by capitalizing on their cultural and linguistic strengths (Gay, 2010). Culturally responsive pedagogy (CRP) is a term coined by Ladson-Billings (1995) to refer to a theoretical model that addresses student achievement as well as helps students to accept and affirm their cultural identities. This stems from the recognition that learning occurs differently across cultures, yet the achievement of all students must be adequately supported. Culturally responsive teaching (CRT) thus originates from CRP and is defined as the use of cultural characteristics, experiences, and perceptions of diverse students in order to teach them more effectively (Gay, 2002). Within the context of the mathematics classroom, this includes practices to promote mathematical thinking, cultural and linguistic funds of knowledge, and issues of power and social justice in mathematics education (Aguirre & Zavala, 2013).

More specifically for ELs, researchers have explored methods of incorporating linguistically responsive teaching (LRT; Goldenberg, 2013) such as drawing on available resources such as diagrams and capitalizing on native language skills and home experiences to make instruction meaningful (Moschkovitch, 2013). Recent theorists have emphasized the importance of a pedagogical approach called translanguaging in which educators promote the use of multiple languages dynamically in ways that reflect natural language use within bilingual communities and recognizes that all of students' languages are integrated and constantly active (MacSwan, 2017). This approach is intended to support EL students' socio-emotional well being and promote their bilingual identities (García, 2009).

This paper will draw from the research and literature on culturally and linguistically responsive teaching approaches to modify schema-based instruction. Several components of traditional SBI incorporate features recommended within CLR literature, such as the use of visual diagrams, explicit instruction, and the promotion of mathematical discourse (Lucas, de Oliveira, & Villegas, 2014). Schema-based instruction incorporates visual representations, which are often used in mathematics research with ELs (e.g., Kim, Wang, & Michaels, 2015) as well as explicit instruction on word problem semantics, which may help ELs develop their academic language proficiency (Orosco, 2014).

Additional components will also be added in to capitalize on the linguistic strengths of the students as modeled in the study by Driver and Powell (2017). The students in that study were allowed to use their first language; however not all student groupings were homogenous in terms of first languages spoken and therefore first language use varied. The present sample included students whose parents reported Spanish as their home language, and were thus encouraged to use Spanish to facilitate discussion of the mathematics content. The present study also explicitly incorporated students' experiences and culture by prompting discussions about students' lives and experiences and using the information to develop relevant word problem teaching examples (Driver & Powell, 2017).

Purpose

The purpose of this study was to evaluate the effectiveness of CLR-SBI to improve the performance of mathematics word problem solving in a sample of Spanish-speaking ELs. An intervention that targets word problem solving skills, schema-based instruction, was adapted to integrate culturally and linguistically responsive approaches. Schema-based instruction has shown effectiveness with native English-speaking students at risk for and with MD, but currently has minimal evidence with an EL population.

Research Questions

The following three research questions directed the research methods of this study.

1. Does culturally responsive schema-based instruction improve Spanish-speaking EL students' performance on word problem solving probes compared to baseline condition?
2. Are the effects of culturally responsive schema-based instruction on word problem solving performance maintained when measured six weeks following intervention implementation?
3. What are the student perceptions of culturally responsive schema-based instruction?

Significance

The current study contributes to the knowledge base on effective strategies for improving the mathematics performance of ELs. Randomized controlled trials have investigated the effectiveness of SBI to improve math word problem solving performance of students with and without MD (Jitendra, Griffin, McGoey, Gardill, Bhat, & Riley, 1998). This study extends that literature to a new population of students by examining the effectiveness of SBI to improve the math word problem solving performance of Spanish-speaking ELs with or at risk for MD. This study also extends previous literature on a culturally and linguistically responsive schema intervention (Driver & Powell, 2017) using the schema-based instruction approach developed by Jitendra and colleagues (e.g., Jitendra & Hoff, 1996) which has been modified to be responsive to ELs. A multiple probe design across participant groups was used to experimentally test the effectiveness of CLR-SBI to improve the word problem solving performance of seven second and third grade ELs.

Organization of the Dissertation

Following the definitions outlined next, a literature review will be presented, which will present a background of education for ELs and what is known about ELs in the math classroom specifically. Theoretical and practical issues of how ELs learn mathematics will be explored through the lens of culturally responsive pedagogy. The literature review will also include an overview of the word problem solving literature with an emphasis on schema-based instruction. Following the literature review, the methods used in this study including participants and setting, measures, conditions, and procedures are explained. Next, the results of the study will be presented using visual analysis to answer each of the research questions. Finally, there will be a discussion of the results and conclusions.

Definitions

English learner: English learner (EL) in this study shall be operationally defined in accordance with the Minnesota state criteria as a student who uses a language other than English, as declared by a parent or guardian, and who lacks the necessary English skills to participate fully in academic classes taught in English, as determined through appropriate language assessment instruments, observations, teacher judgment, or parent recommendation (Minnesota Department of Education, 2017).

Bilingual: Any person who speaks or is currently learning more than one language, which may or may not include English (e.g., Bernardo, 2005). In this document the term bilingual will thus be used in reference to a broader range of languages and language abilities than the narrowly defined EL population of students described above. Bilingual can also refer to education programs that offer instruction in two languages simultaneously (Rhodes, Ochoa, & Ortiz, 2005).

English as a second language: English as a second language (ESL) refers to the instruction of EL students in school (Rhodes et al., 2005). ESL programs may include some home language support or may not. Students are typically pulled out for 30-45 minutes of ESL support daily with the goal of English language development (García, 2009).

Dual-language instructional model: A programming model for ELs that uses the student's L1 to help develop their knowledge in the targeted second language, English. This includes bilingual transition programs, which gradually transition instruction from L1 to L2 and bilingual immersion programs, which aim to develop proficiency in L1 and L2 simultaneously (Albers & Martinez, 2015).

Hispanic: The term Hispanic will be used throughout the paper to describe the ethnicity of the student population. Although Latino is another widely used term to describe a similar population of people, Hispanic was chosen because it reflects a population of people who come from Spanish-speaking Latin America specifically.

Schema-based instruction: Schema-based instruction is an approach developed by Jitendra and colleagues that teaches students to use schematic diagrams to solve addition and subtraction word problems (e.g., Jitendra & Hoff, 1996).

Schema intervention: An umbrella term for an approach used to help students become more proficient at solving mathematics word problems. Schemas are used to help students to recognize that word problems fall into several word problem types and to apply solution strategies based on those types. Interventions that use this approach utilize strategy instruction to prime the underlying problem structure of word problems. Three independent groups of researchers have investigated the efficacy of this approach (e.g., Fuchs et al., 2014; Jitendra et al., 2013; Xin & Zhang, 2009).

CHAPTER 2

Literature Review

The following chapter will provide background information about EL education in U.S. schools including regulations on EL identification, accountability, teacher development, and programming. Policy will also be discussed at the state and local district level for the schools in which data collection took place. Next, EL educational outcomes in mathematics will be described as well as the theoretical considerations of the mathematics learning of ELs. A review of the literature on culturally responsive pedagogy will be presented as well. This will be followed by a discussion of word problem solving broadly and the challenges faced by ELs in this area of mathematics. Finally, previous research on schema-based instruction will be examined.

Background of EL Education in U.S. Schools

The student population in U.S. schools is becoming increasingly heterogeneous in terms of linguistic, cultural, and racial diversity (Snyder et al., 2017). ELs are the fastest growing segment of the school population and approximately 22% of all public school students speak a language other than English in the home (Federal Interagency Forum on Child and Family Statistics, 2017). Overall the student population in the U.S. increased by 8.5% between 1997 and 2008, while the population of ELs increased by 53.2% during the same time period, indicating it is increasingly likely that educators will have at least one EL student in their classroom (Batalova & McHugh, 2010). The EL population growth in Minnesota is also high, consistent with the national trends, and increased by 129% in that same time period (Batalova & McHugh, 2010). Recent statistics show that around 68% of all public schools nationally have at least one EL student enrolled (U.S. Department of Education [DOE], 2009).

Given the increasing cultural and linguistic diversity in public schools, legislation has been introduced to ensure that public schools are addressing the needs of linguistically diverse students. Federal legislation has been written to address EL identification, accountability, teacher development, and programming. First, in order to identify EL students, Title III of the Every Student Succeeds Act created a new provision that each state must develop standardized statewide entrance and exit procedures for ELs (ESSA, 2015). The amendment further requires that any student who may be an EL must be assessed according to state procedures within 30 days of enrollment in a school in the state. States have developed a variety of methods for identifying ELs and assessing English language proficiency (ELP). The identification process generally begins with a home language survey followed by an assessment of ELP (U.S. DOE, 2016). There are some concerns about the validity of these measures for identifying ELs. First, home language surveys may be influenced by parents' interpretations of the questions and therefor may give inconsistent information for a variety of reasons (Abedi, 2008). English language proficiency tests are designed to be more objective sources of information, however without a single consistent national assessment, states continue to have varying classification processes.

Second, Title I of ESSA requires annual assessments of English language proficiency in order to measure ongoing progress of these students (ESSA, 2015). ESSA does not mandate progress goals, rather each state is responsible for creating an accountability system that measures at least four academic goals, including ELP, and one non-academic indicator, such as student engagement (August, 2016). These accountability systems must then be submitted to the U.S. Department of Education to be peer reviewed. In terms of when progress must be measured, ESSA has given states a choice for EL students (ESSA, 2015). They may choose to exempt ELs from the first round of academic proficiency assessments and begin measuring their progress after they have been in a U.S. school for one year; or they may choose to give ELs the academic proficiency assessments in their first year, but exclude the results from their accountability system and measure their growth in the second year and proficiency beginning in their third year. Whichever option they choose, all states must continue to monitor EL academic proficiency as a group for four years to provide evidence of programming effectiveness and improvement (ESSA, 2015). Federal legislation has created several regulations and guidelines to help schools meet these accountability standards.

Third, regulations have been developed to guide teacher and staff development standards. ESSA requires that Title III funds must be used to provide effective professional development for teachers of ELs (U.S. DOE, 2016). In addition to being effective, these programs must be sustained, intensive, collaborative, job-embedded, data-driven, and classroom-focused.

Finally, schools also have programming options to support the EL population in alignment with several Supreme Court rulings and Title III funding requirements. The U.S. Supreme Court determined that school districts are required to provide EL students the necessary supports to overcome the educational barriers associated with not being able to comprehend instruction (*Lau v. Nichols*, 1974), and established three criteria in regards to bilingual education programs: (a) the program must be based on sound educational theory, (b) the program must be implemented effectively with resources for personnel, instructional materials, and space, and (c) after a trial period, the program must be proven effective in overcoming language barriers (*Castañeda v. Pickard*, 1978). In addition, Title III of ESSA provides funding requirements for schools to provide educational programming aimed at helping ELs achieve English language proficiency and meet state academic content standards (U.S. DOE, 2016).

The most common type of programming for ELs is some form of ESL instruction which may include pull-out, stand-alone, or co-teaching (Albers & Martinez, 2015). The focus of ESL instruction is on developing proficiency in the English language and is usually provided in English only. Immersion programs provide support for EL students from trained bilingual or ESL certified teachers who have strong receptive skills in the students' first language, so although the instruction is all conducted in English, students may use their native language in the classroom (Rennie, 1993). Submersion programs place EL students in regular mainstream English-only programs with little or no support or services with the assumption that they will learn English naturally (U.S. DOE, 1999). Content based instruction is an English-only model in which ELs are provided with instructional materials, learning tasks, and classroom techniques from the content areas as the mode for developing language proficiency (U.S. DOE, 1999). However, some evidence suggests even the highest quality ESL programs only close about half of the total achievement gap between ELs and their native English-speaking peers (Thomas & Collier, 2002).

The least common approach to instruction of EL students are dual-language models (Albers & Martinez, 2015). Dual-language models incorporate students' native language, or L1, in one or more subjects to help develop English language proficiency, thereby using students' bilingual knowledge to bridge to new knowledge across the curriculum. Despite being the least common approach, the existing evidence on student achievement outcomes favors dual language models (e.g., Slavin & Cheung, 2005). One national longitudinal report found bilingually educated students outperformed monolingually educated students in academic achievement across all subjects (Thomas & Collier, 2002). While there is modest evidence to suggest that dual language programs produce better outcomes in English than English based approaches, there is no question on the improved native language outcomes associated with dual language programs

(Slavin, Madden, Calderón, Chamberlain, & Hennessy, 2011). Given the cultural, intellectual, and economic benefits of bilingualism, programs that achieve equitable English language outcomes while producing improved native language simultaneously ought to be favored (Bialystok, 2001).

In addition to being the approach with the most promising achievement outcomes, dual language models are also the most favorable option from a social perspective. Schools play a key role in social and cultural reproduction, and what is taught in schools reflects cultural values (Apple, 1982). Schools, therefore, play a significant role in regulating and mediating access to language as a resource (García, 2009). It can also be seen as a way for students to interact with their own communities and with others (García, 2009).

Background of EL education at the state and district level. To further clarify and guide educational practices for ELs, there are policies at the state level in Minnesota that influence EL identification, accountability, teacher development, and programming. Minnesota legislation has developed standardized procedures for EL identification, entrance, and exit in response to ESSA mandates (MDE, 2017). Manuals were developed with step-by-step procedures and criteria for all identification, entrance, and exit decisions for Minnesota EL students. Entrance is determined by a standardized home language survey, the MN Language Survey (MNLS), given to all students upon enrollment, followed by an English language proficiency screener for all students who understand more than one language based on the MNLS.

In terms of accountability, in accordance with Title III of ESSA, Minnesota has mandated that all ELs must participate in the administration of ACCESS for ELLs, which measures English language proficiency, and the Minnesota Comprehensive Assessment (MCA), which is the state academic content achievement assessment (Minnesota Department of Education [MDE], 2017). ACCESS for ELLs is used to determine the proportion of EL students making progress in English and the proportion of EL students who have attained English language proficiency in Minnesota. The MCA is used to determine the proportion of ELs making AYP in meeting grade-level academic standards in English language arts and mathematics. Recently arrived ELs are required to take the MCA within their first year, however their first year results are not included in accountability calculations (MDE, 2017).

In addition, the Minnesota Learning for English Academic Proficiency and Success (LEAPS) Act was passed in 2014, and set a high standard for districts across the state (King & Bigelow, 2017). The purpose of LEAPS was to reform legislation around EL education including academic English proficiency, grade-level content knowledge, and multilingual skills development (Minnesota Education Equity Partnership [MnEEP], 2015). To do so, LEAPS modified laws regarding EL education from early learning through adult learners' statutes, set expectations in teacher and administrator development and licensure, and established new directives regarding accountability (MnEEP, 2015). Specifically, LEAPS required all schools to report on the native language academic literacy of EL students in addition to their English proficiency and academic performance (MN LEAPS Act, 2014). This is in alignment with the law's expectation that home, native language skills are to be viewed as an asset to be used to develop English proficiency and content area knowledge (MnEEP, 2015).

In terms of professional development, Minnesota statutes require professional development opportunities for all staff working with English learners which are (a) coordinated with the district's professional development activities, (b) related to the needs of English learners, and (c) ongoing (MN Statute § 124D.61, 2017). In addition, LEAPS requires districts to provide the appropriate tools, resources, and professional development to enable EL students to become career and college-ready (MN LEAPS Act, 2014). LEAPS further mandates that staff development should enable teachers to provide instruction that maximizes the linguistic strengths of ELs in their native language to build academic literacy (MnEEP, 2015).

Minnesota statutes also require districts to develop a written plan which articulates the amount and scope of services in programming available by English proficiency level which must be made available to parents upon request (MN Statute § 124D.61, 2017). Minnesota Department of Education legislation has selected three broad second language acquisition frameworks that are supported in Minnesota K-12 schools (MDE, 2016). The first is English language development designed for ELs, which promotes and measures English language proficiency as its target. Second is bilingual education, which is designed for ELs and/or native English speakers and has bilingualism and biliteracy as its goal. Within bilingual education programming, MN legislation further delineates traditional bilingual models, which are designed for ELs from dual language and immersion models designed for ELs and native English speakers. Finally, the third framework is world language education designed for native English speakers and ELs with the goal of developing proficiency in one or more world languages (MDE, 2016).

Osseo Area Schools offer ESL supports for all identified EL students (Osseo Area Schools, 2015). At the elementary level this consists of a minimum of 30 minutes of small group English language services five times a week. Students are placed into five levels based on their English language proficiency, and their level determines the amount of time they are given EL services. Core content support is provided in content areas by small group instruction, co-teaching with general education teachers, or other collaborative services.

EL Mathematics Educational Outcomes

Despite federal regulations, English language learners continue to lag behind their peers academically (U.S. DOE, 2008). The most recent data demonstrated that only ten states, which did not include Minnesota, met their Annual Measurable Achievement Objectives for ELs in the 2008-2009 school year (U.S. DOE, 2012). There is also a persistent achievement gap between ELs and their native English-speaking peers in all areas tested nationally including reading, mathematics, science and writing (NCES, 2019). Although most attention in the literature has focused on ELs performance in reading, ELs also lag behind their same-age peers in mathematics (NCES, 2019).

Overall mathematics proficiency has declined in the most recent NAEP report and is low, suggesting that greater attention to mathematics instruction and intervention is necessary (Kena et al., 2016). This need is even more urgent for EL students. To illustrate the achievement gap between ELs and their native English-speaking peers, 41% of all students categorized as ELs scored below basic on mathematics on the National Assessment of Educational Progress (NAEP) in fourth grade, compared to only 15% of students not classified as EL (Snyder et al., 2017). Fourth grade EL students performed

0.6 standard deviations below non-EL students on the 2015 assessment. Historically, this has also been true for even younger students, with data from 1998 showing that EL students scored lower on mathematics assessments as early as first grade (U. S. DOE, 2008).

Increased attention to math is warranted given how important early foundational mathematics skills are for later achievement. Early math achievement is often predictive of later math achievement (e.g., Mazzocco, Murphy, Brown, Rinne, & Herold, 2013; Watts et al., 2015). Furthermore, in a meta-analysis of six longitudinal datasets, Duncan et al. (2007) found school entry math skills to be more predictive of later reading and math achievement than school entry reading, attention, or socioemotional skills. The importance of math achievement continues throughout the lifespan, impacting important outcomes such as college graduation (U.S. DOE, 2008) and adolescent employment rates (Huang, Pergamit, & Shkonik, 2001).

Theory of Mathematics Learning of ELs

There is a strong theoretical connection between mathematics development and language acquisition. Key theorists and researchers have developed models of second language acquisition that have relevance for mathematics development and can help explain the additional challenges ELs face in the mathematics classroom. The developmental interdependence hypothesis proposed by Cummins (1979) argues that a student's competence in their second language (L2) is functionally dependent on their competence in their first language (L1) when they begin intensive exposure to L2. If L1 development is maintained and promoted after the introduction of L2, both language competencies will benefit, despite the minimized time spent in L2, however the reverse is not true. If a student's L1 stops developing, possibly when minority language children enter an English only kindergarten, parts of their linguistic knowledge will not be fully developed, and therefore they have a difficult time mapping new L2 knowledge onto an incomplete cognitive-linguistic system. This has further implications for the development of new content knowledge such as mathematical concepts. When bilingual students are already familiar with a concept in their L1, all they need to do is add a new label to it in L2 (Cummins, 1979). However, if they are unfamiliar with the concept, then they must simultaneously develop the conceptual knowledge and the language.

The revised hierarchical model proposed by Kroll and Stewart (1994) presents a cognitive model for why this interdependence exists. These cognitive researchers examined the asymmetric connections between bilingual memory representations for vocabulary. Words in a bilingual speaker's two languages are believed to be stored in two separate memory systems, and a third abstract memory system stores concepts that are common to both languages. The revised hierarchical model posits that the memory system for L1 has a direct connection to the underlying concept, and in beginning learners, the connection between L2 and the underlying concepts are mediated through L1 translation. Not until learners become more proficient in their L2 will direct conceptual links be drawn between L2 and the underlying concepts. This helps explain the functional dependence between L1 and L2, because of the vital role L1 initially plays in connecting L2 terms with concepts.

These two language acquisition models are relevant to the development of mathematics content, in that conceptual understanding for beginner ELs will be significantly impacted by the amount of conceptual mathematical knowledge students have in their L1. Without some basic understanding of mathematical concepts, ELs will have nothing to map their new learning onto, and the content instruction may seem meaningless (Cummins, 1979). For example, some evidence suggests Hispanic elementary students who are taught mathematics exclusively in English do not do as well as those taught bilingually (Fillmore & Valdez, 1986).

Building subject matter knowledge in school involves building complex networks of conceptual knowledge, and the amount of prior related knowledge will have an impact on how new knowledge is constructed (August, Carlo, Dressler, & Snow, 2005). Mathematical knowledge is organized in a structured way so that new knowledge can be linked with what is already known (National Research Council, 2001). In this way, mathematics knowledge is hierarchical, with simple clusters of ideas packed into larger mathematical concepts. This structured format of knowledge can pose a challenge to ELs attempting to build their foundational skills in an unfamiliar language.

Additionally, there may be a connection neurologically between areas of the brain that contribute to math and language. Some researchers have argued that there are partially overlapping brain networks for arithmetic and language comprehension (Baldo & Dronkers, 2007), which could have strong implications for how ELs learn math. However, other research has argued that the brain systems that support mathematical thinking are much more nuanced than previously thought (Geary, 2011).

There are also environmental aspects that may contribute to the overall achievement of ELs. Teachers tend to report having limited training in working with students who are not proficient in English (Combs, Evans, Fletcher, Parra, & Jimenez, 2005). One survey reported that only 13.9% of teachers had received more than nine hours of training by mid-year on how to assist EL students during instruction (Master, Loeb, Whitney, & Wyckoff, 2016). This is problematic, because the same study found teachers who had received at least 9 hours of training had greater instructional effectiveness with ELs than teachers who did not receive such professional development.

Culturally and Linguistically Responsive Pedagogy

The education of Hispanic EL students should recognize the unique assets of this population, while also taking a critical stance towards improving the outcomes of a historically underserved minority group. This paper uses a framework of culturally and linguistically responsive pedagogy to accomplish this goal (Ladson-Billings, 1995). The overarching goal of this approach is to make instruction more congruent with the cultural and linguistic practices of diverse students (Gay, 2010). The literature on culturally responsive pedagogy will be discussed broadly, followed by an examination of linguistically responsive pedagogy for ELs, and literature on supporting ELs in the mathematics classroom.

Culturally responsive pedagogy. Culturally responsive pedagogy is a theoretical concept within multicultural education that has many different names including, among others, culturally relevant pedagogy (Ladson-Billings, 1995) and culturally responsive teaching (Gay, 2002). Gloria Ladson-Billings (1995) coined the term culturally relevant pedagogy and outlined a theory based on three criteria: (a) an ability to develop students academically, (b) a willingness to support cultural competence, and (c) the development of critical consciousness. Morrison, Robbins, and Rose (2008) conducted a systematic review of classroom-based research investigating culturally relevant pedagogy. Overall, the review found that much of the literature on this concept was qualitative work, and there were fewer examples available that strive to meet the third criteria, development of critical consciousness, than first two. In addition, this review categorized how researchers have operationalized strategies to meet these criteria.

The first criterion, that students develop academically, emphasizes the need for high expectations for all students and the support from teachers to meet these expectations. Pedagogical strategies that support this criterion include modeling and scaffolding (e.g., Conrad, Gong, Sipp, & Wright, 2004), using students' strengths as starting points, investing in students' success, creating cooperative environments (e.g., Howard, 2001), and setting high behavioral expectations (e.g., Brown, 2004). The second criteria, a willingness to support cultural competence, is important to prevent academic success coming at the cost of cultural identities and psychological well-being (Ladson-Billings, 1995). This can be accomplished by reshaping the prescribed curriculum to reflect non-mainstream content related to students' identities (Banks, 2001), building on students' funds of knowledge to connect students' prior knowledge to what they are learning (e.g., Civil & Kahn, 2001), and encouraging relationships between schools and their communities (e.g., Jimenez & Gersten, 1999). Finally, the third criteria in Ladson-Billings model, the development of critical consciousness, stresses the importance of teachers helping their students recognize, understand, and critique current social inequities (Ladson-Billings, 1995). This can be accomplished through critical literacy instruction (e.g., Conrad et al., 2004), engaging students in social justice work (e.g., Ensign, 2003), discussing the power dynamics of mainstream society (Delpit, 1995), and sharing the power in the classroom (e.g., Jimenez & Gersten, 1999).

Building on the work of Gloria Ladson-Billings (1995), Geneva Gay (2002) further developed the theory of culturally responsive teaching practices. The emphasis of culturally responsive teaching is using cultural characteristics, experiences, and perspectives of diverse students as conduits for effective teaching. This theory is based on the assumption that when students' experiences and frames of reference are used to develop their academic knowledge, education is more personally meaningful and interesting, and more easily and thoroughly learned. Gay emphasizes that culturally responsive teaching is validating, because it acknowledges the legitimacy of cultural heritages as factors that impact students' learning and as worthy content to be taught (Gay, 2010). Culturally responsive teaching affirms that there is a place for cultural diversity in every subject taught in schools and that teachers must be able to modify existing curricula to address the needs of all students in the classroom (Gay, 2002). A hallmark of culturally responsive teaching is the ethic of caring that creates teacher-student relationships marked by patience, persistence, facilitation, validation, and empowerment (Gay, 2010).

Linguistically responsive teaching. Specifically for ELs, research has focused on linguistically responsive teaching (Lucas & Villegas, 2010). The focus of this approach is on language-related issues, which distinguish it from culturally responsive pedagogy. Language issues have received significantly less attention than cultural issues; however both ought to be considered in the education of EL students. Lucas and Villegas (2010) developed a framework for linguistically responsive teachers, based on their work educating culturally responsive teachers and the literature on how to successfully educate

ELs. This framework consists of seven orientations and skills teachers ought to develop to successfully teach ELs.

First, sociolinguistic consciousness requires that teachers understand that students' language use reflects cultural values and membership and thus should be valued within the school context (Price & Osborne, 2000). It also requires an understanding of how language is related to the power dynamics in a particular social context (Nieto, 2002). The second related orientation is thus the value of linguistic diversity (Lucas & Villegas, 2010). When teachers show respect for students' home languages, they encourage EL students' engagement in learning (Lucas, Henze, & Donato, 1990). The third orientation for linguistically responsive teachers, is the inclination to advocate for ELs (Lucas & Villegas, 2010). This advocacy is important to ensure that language issues are not minimized or ignored within the broad educational system.

In addition to these three orientations, Lucas and Villegas (2010) also argued that teachers should develop a set of knowledge and skills to work with ELs. The fourth element in their framework is thus learning about students' linguistic backgrounds, experiences, and proficiencies. ELs are not a homogenous group, so teachers should take the time to understand their students' language skills in order to know what support they will need to be successful in the classroom. Relatedly, teachers should also understand the linguistic demands of the oral and written discourse in their classroom (Cummins, 2000). This will allow them recognize aspects of educational tasks that may be incompatible with the linguistic capabilities of their students and to differentiate accordingly. The sixth element of linguistically responsive teaching is an understanding of the process of second language acquisition (Lucas & Villegas, 2010). Several key principles that are highly relevant to teachers of ELs include the importance of social interaction for language acquisition (Vygotsky, 1978), the difference between conversational and academic language proficiency (Cummins, 1981), and the critical role a students' first language plays in the development of their second (Cummins, 1979). Finally, the seventh element of linguistically responsive teaching is instructional scaffolding (Lucas & Villegas, 2010). Scaffolding refers to the support given to help students engage in academic tasks beyond their current capacity (Gibbons, 2002).

In alignment with a linguistically responsive approach that values linguistic diversity, recent scholars in bilingual education have emphasized the concept of translanguaging. The term was originally coined to refer to the systematic use of two languages for teaching and learning within bilingual education programs (Williams, 1996). Since then the term has been expanded to reflect the notion that all of an individual's languages function together within a unitary or integrated linguistic system (García, 2009; MacSwan, 2017). Linguistically integrated group work is one such practice that allows students use their linguistic resources to support their conceptual and linguistic understandings, and thus is present in many bilingual classrooms (García, 2009).

As a pedagogical approach, translanguaging has been implemented through the use of hybrid language practices in which languages in a bilingual program are intentionally mixed, students are positioned as bilingually competent, and students' bilingual language practices and metalinguistic awareness are celebrated (Palmer, Martínez, Mateus, & Henderson, 2014). Hybrid language practices are modeled by teachers who flexibly switch between languages in order to model bilingualism for students and to mediate understanding (García, 2009). Positioning students as bilingually competent is done by asking students to translate for their classmates and affirming their developing abilities to do so (Palmer et al., 2014). Highlighting metalinguistic awareness can be accomplished by encouraging students to notice similarities and differences between their languages (Palmer et al., 2014). In addition, students with a wide range of proficiencies in their first and second language can use translanguaging to demonstrate knowledge, mediate understandings, and construct meaning (García, Makar, Starcevic, & Terry, 2011). In sum, this approach is designed to support student learning while also affirming linguistic diversity as a value (MacSwan, 2017).

Most of the recommendations within the culturally and linguistically responsive literature base, including the scholarship on translanguaging, are formed based on descriptive literature and qualitative studies (Morrison, et al., 2008). One review examined the empirical literature and summarized three important principles on education for ELs (Goldenberg, 2013). First, generally effective practices are likely to be effective with ELs. Second, on top of sound instructional practices, ELs need additional instructional supports. And third, home languages are a useful resource that can be used to promote academic skills. In regards to the second principle, there is emerging literature within the mathematics domain about practices designed to help ELs succeed.

Mathematics strategies for English learners. Two strategies that are most often implemented in math instruction and intervention with ELs are development of academic language and multimodal representation (Jones, 2017). First, despite language barriers, Driscoll and colleagues (2012) argue that ELs should learn to engage productively in mathematical discourse. This is something that educators need to explicitly focus on developing with this population, given the difficult and challenging nature of mathematics language (Schleppegrell, 2007). Learning academic language is something many students struggle with, and it is especially difficult for ELs because they may not have the same foundation of everyday language on which to extend their proficiency (Driscoll et al., 2012). ELs have been found to be limited in both the depth and the breadth of their vocabulary knowledge (August et al., 2005). This means that ELs not only know fewer words; they also know fewer uses and less about the words they do know. Many terms in mathematics have other meanings in everyday language, but it is less likely that ELs will know these multiple meanings. While students may learn communicative English relatively quickly, academic language requires much more time and effort for ELs to acquire (Dixon et al., 2012).

Teachers need to understand that math is more involved than teaching about numbers and must broaden their approach to address EL students' understanding of the language as well (Warren & Miller, 2015), including the communication skills necessary to competently engage in mathematical discourse (Moschkovich, 2010). Strategies designed to develop academic language include explicitly teaching academic vocabulary throughout math lessons (Livers & Bay-Williams, 2014), asking open-ended questions, modeling vocabulary in context (Holland, Palacios, Maerritt, & Rimm-Kaufman, 2016), and reviewing or previewing the content in students' first language (Nguyen & Cortes, 2013). These strategies may help students build on their own everyday language to extend their mathematical language proficiency.

Second, given the challenge of navigating the learning of a second language and the language associated with mathematics, Driscoll and colleagues (2012) recommend that instruction incorporate multiple modes of representation to give ELs a variety of ways of understanding and expression. As proposed in the developmental interdependence hypothesis, ELs who have not developed mathematical concepts in their first language will simultaneously have to develop language and conceptual knowledge (Cummins, 1979). One way that instructors can attempt to tackle this challenge is by developing students' competence through other modes besides language. Richard Lesh (1981) identified five distinct types of representation systems that occur in mathematics learning: spoken language, written systems, real scripts, static pictures, and manipulative models. These five systems are all interconnected and each can support the development of the others. The translations between systems are important in mathematics pedagogy in order to develop conceptual understanding. Lesh and colleagues (1987) further argue that when a student has difficulties in one of the systems, the other systems can be used to both strengthen and bypass that system. For ELs this means that although they often struggle with the system of spoken language, other modalities such as diagrams and manipulatives can be used to develop conceptual understanding and strengthen language.

Qualitative research suggests that when teachers utilize more than one mode of communication, their students in turn can express themselves through a variety of methods as well (Morales, Khisty, Chval, 2003), giving ELs flexibility with which to engage in the mathematics content. Multiple modes to communicate mathematical principles such as pictures, diagrams, presentations, written explanations, and gestures (Driscoll et al., 2012) are suggested for classrooms with ELs.

A review of instruction and intervention literature with ELs showed that these two strategies for developing the math skills of ELs were used frequently (Jones, 2017).

Multimodal representations were used in 71% of the reviewed studies and development of academic language was used in 47%. Incorporating these strategies into mathematics instruction with ELs is therefore a promising approach based on the current literature available.

Word Problem Solving

The National Mathematics Advisory Panel (NMAP) Report indicated that the key elements of early mathematics learning include whole and rational number knowledge (NMAP, 2008). Central to both of these broader areas is student proficiency with word problem solving, which is a key focus of intervention support in the Institute for Education Sciences (IES) Practice Guide on Response to Intervention (RTI) in mathematics (Gersten et al., 2009). Word problem solving has also been linked to algebraic reasoning (Fuchs et al., 2014) which is seen as a clear gateway to later achievement; students who complete Algebra II are more than twice as likely to graduate from college (NMAP, 2008). Therefor there is a clear emphasis throughout the NMAP Report on the preparation for students to succeed in algebra. Experts have identified the translation of verbal information into numerical expressions as a core activity of algebraic competence, which can be developed through word problem solving (National Research Council, 2001). As an illustration of the weight experts place on word problem solving, the Institute of Education Sciences Practice Guide recommends that for children in grades K through 8, focused word problem solving instruction be provided for all children who are not meeting mathematics proficiency expectations (Gersten et al., 2009).

Word-problem solving is a consistent challenge in the mathematics classroom, and can be of concern even when arithmetic skills are adequate (Swanson, Jerman, &

Zheng, 2008). Teachers report that word-problem solving is one of the most challenging skills for students in mathematics (Jonassen, 2003). This is problematic given that word problems are the best school age predictor of employment and wages in adulthood (Murnane, Willett, Braatz, & Duhaldeborde, 2001). Word problems are challenging because of the sequence of skills necessary to find successful solutions. Students need to (1) understand the language of the problem, (2) select the appropriate algorithm, (3) execute the correct step-by-step plan, (4) self-monitor throughout the process, and (5) generalize the strategies they have learned to new problems (Codding, Volpe, & Poncy, 2017). Research on word problem solving has often focused on students who are at risk for MD so the literature findings may be most salient to that population (Jitendra & Xin, 1997).

The use of mathematical representation of problems and cognitive strategy instruction are two strategies found in the word problem solving literature with a strong evidence base (Zhang & Xin, 2012). A meta-analysis conducted by Zhang and Xin (2012) found problem structure representation to be the most effective intervention for word problem solving of students with MD and cognitive strategy instruction to be the second most effective approach. Jitendra and colleagues conducted a recent systematic review of the literature and found mathematical representation of problems to be an evidence based intervention based on group design quality criteria (Jitendra, Nelson, Pulles, Kiss, & Houseworth, 2016).

Traditional approaches to problem solving which only instruct students to translate the word problems into mathematical equations are ineffective because they fail to instruct students on the deep structure of the problems (Jonassen, 2003). Therefore, effective strategy instruction incorporates instruction on the underlying structures of the word problems. Strategy instruction priming the underlying problem structure addresses this method of instruction and a recent meta-analysis determined this practice to be evidence-based using stringent group design methodological criteria (Jitendra et al., 2015). Three independent groups of researchers have investigated the efficacy of strategy instruction priming the underlying problem structure of word problems (e.g., Fuchs et al., 2014; Jitendra et al., 2013; Xin & Zhang, 2009). Each line of research has investigated this strategy with varying key components.

First, Fuchs and colleagues developed a program called schema-broadening instruction which emphasizes the importance of explicitly teaching for transfer so students learn to recognize broad schemas of problems that require the same solution methods (e.g., Fuchs et al., 2003; Fuchs et al., 2014). Examples of features for which students are taught to transfer their knowledge include problems that include irrelevant information or present information in charts, graphs, or pictures (Fuchs, Seethaler, et al., 2008). Schema-broadening instruction teaches students to construct algebraic equations that represent the underlying problem structure (Fuchs et al., 2009). Variations on this approach have been found to be successful when implemented class-wide in third grade general education classrooms (Fuchs et al., 2003) and with third grade students with math and reading difficulties in supplemental tutoring sessions (Fuchs, Seethaler, et al., 2008). Schema-broadening instruction has shown improved outcomes on near and far transfer word problem solving (e.g., Fuchs, Fuchs, Finelli, Courey, & Hamlett, 2004) as well as improved pre-algebraic reasoning (Fuchs et al, 2014).

Second, Jitendra and colleagues developed the schema-based instruction (SBI) approach which has four key components, (a) visual representation of problems, (b) priming the underlying problem structure, (c) explicit instruction, and (d) metacognitive strategy instruction (Jitendra et al., 2013). The visual representations of the problems using diagrams are a distinguishing component of SBI and are designed to help students recognize the mathematical relations between quantities and organize the information from the problem (e.g., Jitendra et al., 2013; Jitendra & Hoff, 1996). Jitendra and colleagues have implemented their program with elementary (e.g., Jitendra & Hoff, 1996) and secondary students (e.g., Jitendra, DiPipi, & Perron-Jones, 2002). The curriculum for elementary students focuses on the additive problem structures of addition and subtraction word problems (e.g., Jitendra et al., 3013) while the program for secondary students identifies the multiplicative problem structures involved in ratio and proportion problems (e.g., Jitendra, Harwell, Dupuis, & Karl, 2017). A meta-analysis of mathematics interventions for secondary students with learning disabilities and math difficulties found visual representations combined with other strategies such as priming the underlying problem structure to be the most effective instructional approach (Jitendra et al., 2018).

SBI has been shown to be an effective intervention when implemented individually (e.g., Jitendra & Hoff, 1996), in small group tutoring (e.g., Jitendra et al., 2013), and class wide (e.g., Jitendra et al., 2009). A majority of the research on SBI with elementary students has focused on outcomes for students with math difficulties (e.g., Jitendra et al., 2013). However, the intervention has also demonstrated improved outcomes for students with emotional and behavioral disorders (Jitendra, George, Sood,

& Price, 2010), autism spectrum disorder (Rockwell, Griffin, & Jones, 2011), and combined autism spectrum disorder and intellectual disability (Root, Browder, Saunders, & Lo, 2017). Details of SBI implementation for elementary school students are presented below.

Finally, the third group of researchers that have investigated strategy instruction priming the underlying problem structure is Xin and colleagues (e.g., Xin & Zhang, 2009). Xin and Zhang (2009) coined the program conceptual model based problem solving (COMPS) which emphasizes expressions of mathematical relations such as *part + part = whole* and *factor* x *factor = product* (Xin, Wiles, & Lin, 2008). As with SBI, COMPS uses visual diagrams to map the mathematical relations (Xin et al., 2008). COMPS has shown improved outcomes on word problem solving for fourth and fifth grade students with or at risk for math difficulties (Xin et al., 2008; Xin & Zhang, 2009; Xin, Zhang, Park, Tom, Whipple, & Si, 2011).

Overall the work conducted by Jitendra and colleagues, Fuchs and colleagues, and Xin and colleagues provides robust evidence of strategy instruction that primes the underlying problem structure (Jitendra et al., 2015). The SBI approach developed by Jitendra and colleagues is unique in that it incorporates schematic diagrams that represent the underlying problem structure of the various word problem types (e.g., Jitendra et al., 2013). The COMPS approach developed by Xin and colleagues also utilizes schematic diagrams, however their approach teaches students one general model for all problem types, such as the *part + part = whole* relationship for additive problems (e.g., Xin et al., 2008). The schema-broadening approach developed by Fuchs and colleagues teaches students to organize the information from the word problems in mathematical equations as opposed to schematic diagrams (e.g., Fuchs et al., 2014). Additionally, schema-broadening instruction incorporates explicit instruction on transfer to novel problems (Fuchs et al., 2003). SBI has been investigated with elementary (e.g., Jitendra et al., 2013) and middle school students (e.g., Jitendra et al., 2009), whereas schema-broadening instruction and COMPS have been investigated primarily in elementary schools (e.g., Fuchs et al., 2014; Xin et al., 2008). SBI and schema-broadening instruction have significant research support with more than ten studies each investigating their effectiveness, whereas there is relatively less research support for the COMPS approach which is based on three studies.

Word Problem Solving and ELs

Mathematics is multifaceted but language acquisition is imperative for word problem solving. Word problem solving differs from other forms of mathematics competence because students must first decipher the text describing the problem situation. Students need to understand the linguistic structures that imply mathematical operations such as relational terminology like “more than” or “less than” in order to extract a mathematical model (Schumacher & Fuchs, 2012). Surface structure of math word problems can also pose a challenge for ELs if they have problems comprehending any of the words in the text or in terms of working memory resources necessary to translate that are then no longer available for arithmetic calculations (Shaftel, Belton-Kocher, Glasnapp, & Poggio, 2006). In addition, word problems often have limited information provided that may help in providing contextual cues to support reading comprehension (Ambrose & Molina, 2014). Finally, unfamiliarity with story problem contexts can hinder word problem performance (Oviedo, 2005) and any student that does not belong to the majority cultural group, such as ELs, is disproportionately impacted by unfamiliar contexts (Celedón-Pattichis, 2003).

Despite these challenges, ELs also have several strengths that support their success in word problem solving. First, despite having smaller English vocabularies than their native-English-speaking peers, ELs are more adept at inferring the meaning of words through context clues and persisting in the face of ambiguity (Marinova-Todd, 2012). Second, ELs have an advantage when it comes to attentional control and executive functioning which comes from the routine of keeping two language systems apart (Kempert, et al., 2011). However, research has found that the cognitive benefits of bilingualism are greater for ELs with high language proficiency levels than those with low language proficiency (Kempert et al., 2011).

Schema-based instruction. Given the paucity of research that has examined math interventions with ELs, it is necessary to turn to intervention research more broadly to support these students. Schema-based instruction is comprised of four key ingredients, (a) visual representation of problems, (b) priming the underlying problem structure, (c) explicit instruction, and (d) metacognitive strategy instruction (Jitendra et al., 2013). Three of these ingredients (visual representation, priming the underlying problem structure, and metacognitive strategy instruction) were described above as evidence based practices for teaching mathematical word-problem solving. The fourth, explicit instruction, was found to be the most effective strategy in a recent meta-analysis on teaching students with mathematics learning difficulties (Dennis et al., 2016). A previous review of schema-based instruction found five studies that investigated SBI in elementary schools between the years of 1996 to 2009 (Powell, 2011). An additional six studies between 2011 and 2017 investigated SBI with elementary aged students for a total of 11 studies. Of these 11 studies, eight were conducted by Jitendra and colleagues. Five studies were randomized controlled trials, five were single case design studies, and one was an informal classroom experiment without a control group. A total of 493 students participated in these studies.

The first key ingredient in SBI is the use of visual representations through the use of diagrams to depict the problem schemas (Powell, 2011). Each type of problem has a unique diagram that helps to convey the underlying mathematical structure. This type of visual representation is more effective than pictorial or iconic representations that focus on the surface elements in the problem (van Garderen & Montague, 2003). Zahner and Corter (2010) found that visual representations can be effective in problem solving, but only when an appropriate representation is chosen. The visual representations used in schema-based instruction are included in Appendix A. These representations help reduce the cognitive memory demand associated with word problems because all of the information from the problems is organized within the diagrams (Jitendra et al., 2013). In addition to organization, diagrams also help to make abstract relationships concrete and can support the strategy formulation stage of problem solving (Zahner & Corter, 2010).

The second key ingredient in SBI is priming the underlying problem structure using the problem’s schema (Powell, 2011). Addition and subtraction word problems are thus grouped into three different schemas (change, group, or compare type problems), which emphasize the mathematical structure of the problems (Riley, Greeno, & Heller, 1983). There are two unique underlying problem structures in ratio and proportion problems that are represented as multiplicative compare and vary problems in SBI

(Jitendra, DiPipi, & Perron-Jones, 2002). Each of the three problem types for addition and subtraction problems is explained below.

Change. Change problems involve one object or thing that increases or decreases in amount or value. An example of a change type problem is, "Jose was carrying 6 eggs for breakfast. He dropped 2 eggs. How many eggs does Jose have left?" The unknown quantity in change problems can be in start position, the change position, or the result position. In addition, change problems can also represent an increase or decrease in quantity. Combinations of unknown quantity and increase or decrease problems result in six different change type problems that fit in the change schema.

Group. Group type problems are sometimes also referred to as combine problems. These problems combine two distinct things or parts into a large group or a whole. An example of a group problem is, "Samuel went to the grocery store and bought 4 apples. He also bought 3 bananas. How many pieces of fruit did Samuel buy altogether?" In group type problems the unknown quantity can be one of the subsets or it can be the total amount. There are only two different group type problems based on whether the unknown quantity is either the large group or one of the smaller groups.

Compare. Compare type problems involve two people or objects that are comparing the amounts of one thing, or one person comparing the amounts of two different things. An example of a compare type problems is, "Sofia and Ana are playing with marbles. Sofia has 7 marbles. Ana has 5 marbles. How many marbles does Sofia have more than Ana?" In compare type problems the unknown quantity can be in the difference position as in the previous example, in the compared quantity position, or in the referent position. The problems can also be presented with more or less resulting in a total of six different possibilities for compare type problems.

The third key ingredient in SBI is explicit instruction on the use of problem solving heuristics. Explicit instruction has been found to have moderately strong evidence of effectiveness in mathematics achievement of at-risk students (Baker, Gersten, & Lee, 2002). In SBI explicit instruction is focused on modeling the problem solving process using a four-step problem solving heuristic (Jitendra et al., 2013). The purpose of the heuristic is to get students to focus on problem comprehension, problem representation, planning, and problem solution. In SBI the problem solving heuristic is taught using the FOPS acronym (F – Find the problem type, O – Organize information in the problem using a diagram, P – Plan to solve the problem, S – Solve the problem).

Finally, the fourth key ingredient in SBI is metacognitive strategy instruction (Jitendra et al., 2013). Metacognitive skills involve the skills necessary to regulate learning and problem solving such as task analysis, planning, monitoring, and checking (Flavell, 1979). Metacognitive skills are a strong predictor of problem-solving performance even when general intelligence is controlled for (van der Stel & Veenman, 2008). Schema-based instruction teaches metacognitive skills through modeling by using think alouds on how to monitor and reflect on the problem solving process (Jitendra et al., 2013). Tutors model and scaffold instruction to encourage students to think deeply about the problem solving process (Jitendra et al., 2013).

Culturally and Linguistically Responsive Schema-Based Instruction

One study has explicitly adapted a schema-based approach to teaching word problem solving to incorporate culturally and linguistically responsive instruction. Driver and Powell (2017) implemented a schema instruction intervention that had been modified to include culturally and linguistically responsive practices with eight Spanish-speaking and one Arabic and Nuba speaking third grade students at risk for MD. Their study utilized quasi-experimental methodologies to compare the performance of their study sample to a representative sample of third grade students. Their intervention approach followed traditional schema intervention methods (e.g. Fuchs et al., 2014) with the addition of six elements of culturally and linguistically responsive mathematics instructions. Specifically, they incorporated (a) explicit measurable lesson objectives, (b) facilitated oral discussions with students, (c) allowable native language use, (d) graphic organizers and manipulatives, (e) incorporation of students' own ideas and experiences, and (f) relevant instructional examples. Results of this study showed that all students demonstrated significant improvement in word problem solving performance following intervention.

The current study used the schema-based instruction program developed by Jitendra and colleagues (2013), because of key components that are in alignment with the culturally and linguistically responsive teaching practices outlined above (Gay, 2010; Ladson-Billings, 1995; Goldenberg, 2013). In accordance with the first principle identified by the review conducted by Goldenberg (2013), SBI is an instructionally sound intervention and therefore can serve as the foundation for an intervention approach specific to ELs.

In alignment with the second principle of Goldenberg's review (2013), SBI incorporates several instructional components that support ELs in math, namely multimodal representation and academic language (Driscoll et al., 2012). The multimodal representation recommendation is incorporated in SBI through the use of schematic diagrams to assist in problem solving (Jitendra & Hoff, 1996). Visual representations are effective when they reduce the cognitive memory demands, organize and summarize story information, and make abstract relationships concrete (Presmeg, 2006). The schematic diagrams used in SBI help students understand the relationships described in the word problems as opposed to pictorial representations, which only focus on the physical appearance of the items in the problems (Jitendra et al., 2013).

Schema-based instruction also incorporates several strategies that assist in the development of academic language. First, SBI uses explicit instruction that includes verbalizations of the thought processes instructors use in problem solving (Jitendra et al., 2013). This provides ELs with a model of mathematical discourse that helps students develop their own mathematical communication skills (Moschkovich, 2010) and models vocabulary use in context (Holland et al., 2016). Instruction in SBI also includes explicit instruction on the semantic relationships within word problems (Jitendra & Hoff, 1996). Semantic instruction is more nuanced than simply identifying key words such as *altogether* to indicate addition, or *left* to indicate subtraction, which is an ineffective strategy for solving word problems (Jitendra & Xin, 1997). These strategies may make schema-based instruction an ideal intervention to implement with ELs to support their mathematics word problem solving.

In addition to the culturally and linguistically responsive practices present in traditional SBI, the current study incorporated several additional practices in alignment with the preliminary study conducted by Driver and Powell (2017). First, the intervention was implemented in peer dyads or triads to encourage mathematical discussions. Culturally responsive pedagogy emphasizes the benefits of creating cooperative learning environments (Ladson-Billings, 1995). Linguistically responsive teaching also highlights the importance of supporting social interactions to promote language development (Lucas & Villegas, 2010). Mathematical discussions were encouraged by instructing the students to complete the practice problems at the end of each lesson together.

Second, students in this study were allowed and encouraged to use Spanish as a resource during problem solving (Driver & Powell, 2017). This reflects Goldenberg's (2013) third principle of effective instruction for ELs, using home language as a resource. This adaptation is also in alignment with the translanguaging pedagogical approach by allowing students to use their full linguistic repertoires to make sense of the content (García, 2009). This practice emphasizes strategic hybrid language use, and the use of Spanish was therefore encouraged during peer conversations. Linguistically responsive teaching calls for placing value within linguistic diversity, so this project explicitly emphasized Spanish language use as a resource (Lucas & Villegas, 2010).

The third component adapted to increase the culturally and linguistically responsiveness of SBI was the incorporation of relevant instructional examples (Driver & Powell, 2017). Ladson-Billings (1995) argues for practices that support the cultural competence of students. This can be accomplished by reshaping curricula to make them more relevant to diverse students (Banks, 2001) and building on students' funds of knowledge to connect students' prior knowledge to what they are learning (e.g., Civil & Kahn, 2001). In SBI this was accomplished by cooperatively designing teaching examples with the students based on their experiences and interests. Using relevant experiences as conduits for teaching help students engage meaningfully with the academic content (Gay, 2002) and familiar contexts are supportive of new learning (Kim et al., 2015). These three modifications to SBI are supported by culturally and linguistically responsive pedagogical theories (Gay, 2002; Ladson-Billings, 1995; Lucas & Villegas, 2010) and by the preliminary evidence of the recent study by Driver and Powell (2017). This study seeks to add to this literature by evaluating the efficacy of this culturally and linguistically responsive schema-based instruction.

Summary

To understand how to support ELs who are struggling in mathematics it might be useful to examine the impact of a strong empirically supported word problem solving intervention that has been adapted to incorporate culturally and linguistically responsive teaching practices. The current literature provides suggestions on how to provide instruction to ELs, but the empirical support for these practices is extremely limited. To determine the efficacy of the chosen approach, the following methods were utilized.

CHAPTER 3

Method

Participants

Participants for the present study included seven second and third grade students from two urban elementary schools (School A and School B) in the Midwest region of the United States. Total enrollment in School A was 444 students, 31.9% of whom are English language learners, 11.5% enrolled in Special Education, and 84.9% receiving Free and Reduced-Price Lunch. Total enrollment in School B was 346 students, 39.9% of whom are English language learners, 14.5% enrolled in Special Education, and 76.2%

receiving Free and Reduced-Price Lunch. Demographically School A enrollment was 50.9% Black, 21.2% Hispanic, 20.9% Asian, 5.4% Multiracial, 0.9% White, and 0.7% American Indian/Alaskan Native. School B enrollment was 34.5% Asian, 29.5% Black, 24.6% Hispanic, 5.4% White, 5.4% Multiracial, and 0.5% Native American Indian/Alaskan. The intervention sessions took place in a quiet space including the school psychologist's office or a conference room. This study was approved by the building administrators, the school district's Department of Research, Assessment, and Accountability, and the university's Institutional Review Board (IRB).

Students were selected to participate in the present study through a three-stage process. To be considered for participation in this study students needed to be: (a) identified as an English language learner whose home language is Spanish, and (b) in second or third grade. EL status and home language were determined by school records. Home language surveys were administered for all students and those that report a language other than English spoken in the home were also given the WIDA ACCESS for ELs 2.0. The ACCESS for ELs 2.0 is a language screener designed to assist educators with programmatic placement decisions (Wisconsin Center for Education Research, 2013). EL status in the district is determined by a cut score of 4.5 out of 6 across all domains of the ACCESS for ELs 2.0, with at least one score lower than 3.5 in reading, listening, writing, or speaking.

Once a pool of students was selected based on these criteria, consent forms were sent home for the second phase of the selection process. A consent form is included in Appendix B. All consent forms were sent home in English with a copy translated into Spanish. All translations were conducted by a bilingual education support personnel from an elementary school where data was collected. Active consent was used, so parents were required to send back the consent form if they wished for their child to participate in further screening. All students whose parents sent the consent form back indicating that they gave permission for their child to participate in the study were screened for prerequisite skills. Each student was asked for verbal assent to participate after listening to a developmentally appropriate explanation of the research study (see Appendix C for a script of the explanation).

The third phase of the selection process was to conduct screening assessments to determine: (a) at-risk status for math difficulty, (b) instructional level on prerequisite skills in arithmetic computation, and (c) current level of word problem-solving skills. In this study, at-risk for math difficulty was operationalized as a score at or below the 25th percentile on the AIMSweb concepts and applications mathematics screener (AIMSweb M-CAP). The 25th percentile was chosen because it is a value commonly used to denote at-risk status (e.g. Jitendra et al., 2016; Murphy, Mazzocco, Hanich, & Early, 2007).

A survey level assessment (Shapiro, 2011) was given to the pool of students to determine their instructional level on two digit by two digit addition and subtraction problems with and without regrouping. A survey level assessment consists of administration of a series of curriculum based measurement (CBM) probes of varying difficulties to determine the instructional level of the student (Shapiro, 2011). Instructional level is defined as at least 14 digits correct per minute (DCPM; Burns, VanDerHeyden, & Jiban, 2006). Based on the survey level assessment data, it was determined that limiting the student population to students in the instructional level on double digit addition and subtraction would eliminate 5 of the 7 students who met all other study criteria. Previous work has found that roughly twice as many students have concurrent difficulties in computation and word problem-solving than difficulty in one area (Fuchs, Fuchs, et al., 2008) and most students do not meet grade level expectations for addition and subtraction fluency (Stickney, Sharp, & Kenyon, 2012). Therefore, this study included participants across all levels of computation ability, and provided additional computation support, as outlined below.

A word problem-solving curriculum-based measure (WPS-CBM) was also given as a pre-test to determine the level of WPS ability. Although mathematics risk status was determined by the AIMSweb screening data, any student who scores higher than 50% correct on the CBM-WPS pre-test was excluded from the study (e.g., Jitendra & Hoff, 1996).

Demographics. A total of nine students who were recruited returned signed parental consent forms and gave verbal assent to participate in the study. Of these nine students, two were excluded because they did not meet the initial screening criteria on the M-CAP or WPS probe. This left seven students who participated in the CLR-SBI intervention. For the appropriate number of replications of an effect to be demonstrated in a single case design study, experts recommend the study include a minimum of three participants (Gast, 2014). Table 1 presents student demographic information and screening data for the seven participants. Of the seven participants, five were female. Two students were in third grade, and the other five were in second grade. Five students attended School A and two students attended School B.

Table 1

Participant Demographics

Student	Gender	Grade	School	Group
Jorge	Male	Second	School A	1
Alexa	Female	Second	School A	1
Mia	Female	Second	School A	1
Julieta	Female	Second	School B	2
Oscar	Male	Second	School B	2
Diana	Female	Third	School A	3
Catalina	Female	Third	School A	3

Table 2 provides student WIDA-ACCESS for ELs 2.0 data. A 6.0 represents the highest score possible, and the end of the EL continuum as measured by the WIDA-ACCESS. All students' WIDA-ACCESS composite scores, which include measures of listening, speaking, reading, and writing, fell between 2.0 (Emerging) and 4.0 (Expanding). Listening was the highest area for all students, and each of their scores fell between 5.6 (Bridging) and 6.0 (Reaching). WIDA-ACCESS reading scores ranged from 1.8 (Entering) to 6.0 (Reaching).

Table 2

Participant WIDA-ACCESS Test Scores

Student	ACCESS Composite	ACCESS Listening	ACCESS Speaking	ACCESS Reading	ACCESS Writing
Jorge	3.0	6.0	2.8	4.1	1.8
Alexa	4.0	6.0	2.8	6.0	3.2
Mia	2.1	5.8	2.2	1.8	1.8
Julieta	3.6	6.0	4.4	2.8	2.8
Oscar	2.8	5.0	3.0	2.3	2.3
Diana	3.4	6.0	5.2	1.9	3.1
Catalina	3.2	5.6	1.9	3.0	3.4

Setting

Seven students received the intervention in small groups of 2 or 3, in a quiet office or conference room, three times weekly, for 30 minutes. The students received the intervention during their intervention block or after their core mathematics instruction.

Interventionists

The author and two graduate students in School Psychology and Special Education administered the interventions. The interventionists had graduate level course work in assessment and intervention including training on CBM administration. The graduate student interventionists were trained by the author using a procedural checklist during one hour-long meeting which consisted of modeling the treatment procedure and practice with one another. The author computed the level of proficiency by observing the interventionists using a script and recording whether each step was fully, partially, or not implemented as intended. The interventionists were expected to obtain 100% adherence to scripted steps.

Measures

Screening. Screening was conducted using the AIMSweb Mathematics Concepts and Applications (M-CAP) assessment (Pearson Education, 2012). Mathematics Concepts and Applications (M–CAP) is a brief, standardized test of concepts from the typical math curriculum. The M-CAP was administered in small groups and scored with national norms for the second and third grade sample.

Survey level assessment. Probes for the survey level assessment consisted of six measures from SpringMath: (a) single digit addition, (b) single digit subtraction, (c) double digit addition with regrouping, (d) double digit addition without regrouping, (e) double digit subtraction with regrouping, and (f) double digit subtraction without regrouping consistent with expectations for assessment in mathematics (VanDerHeyden & Burns, 2005). Students were given two minutes to complete each probe. Scores were determined by total number of digits correct per minute.

***Language proficiency*.** Language proficiency was determined in English by language testing completed by the school. English proficiency is measured using the WIDA-ACCESS for ELs 2.0, which includes measures of speaking, listening, reading, and writing.

Language use. Information was gathered to investigate the language use of the student sample. A short survey was given to the general education and EL teachers for each student in the sample. The survey asked (a) what languages the teacher speaks with the students during non-instructional time, (b) what languages the teacher speaks with the students during instruction, (c) what languages they hear the student speaking during academic tasks, (d) what languages they hear the student speaking during non-academic time (e.g. lunch, hallways, recess), and (e) what rules or policies do they enforce about language use other than English in their classrooms. Language use survey data can be found in Table 2.

Progress monitoring. The primary outcome of interest in the current study was the accuracy of problem solving on word problem-solving (WPS) probes. Word problem-solving was measured using WPS probes adapted from the CBM-WPS probes developed by Jitendra, Sczesniak, and Deatline-Buchman (2005). The CBM-WPS probes consisted of six one-step and two two-step addition and subtraction problems. The probes developed by Jitendra et al. (2005) are comprised of a mixture of change, group, and compare type problems. The probes were evaluated for technical adequacy as static and growth indicators (Jitendra, Dupuis, & Zaslofsky, 2014). They were found to have adequate reliability with alpha coefficients ranging from 0.67 to 0.71 and significant predictive validity to the MAP mathematics subtest with a correlation coefficient of .45 ($p < .01$). The probes were also able to provide evidence of growth for third grade students at risk for MD, with all students in the study showing significant average growth rates, $b = 1.30$, $SE(b) = 0.27$, $t = 4.78$, $p < .05$.

For the purposes of this study, the probes were adapted to create probes each comprised of only change and group type problems (see Appendix D for sample probe). This was done by taking all of the available change and group problems from the CBM-WPS probes and then writing new problems that differed in surface contexts and numerical values only. The new probes were designed to be culturally neutral by using contexts familiar to all students, such as the classroom, and choosing names that are popular in the Hispanic culture. Each probe contains four change problems and four group problems, with an even number of addition and subtraction problems. The number of problems with the unknown quantity in each position within the problem was also kept consistent across each probe. In addition, because only one of the three problem types was introduced, only one-step problems were included to avoid mixing problem types within each probe.

Progress was monitored at the end of each intervention session. Students were instructed to solve each problem and show their work by writing the number sentence and complete answer for each problem. They were also told that they may use a diagram if it helps to solve the problems. The interventionist then read each problem aloud and gave students time to work through each problem. After the probes were completed, each student was given a small token (e.g., pencil, eraser, sticker) to reward engagement and effort. Student responses earned one point if they provided the correct answer and one point for the correct label for a total of two points for each problem (Jitendra et al., 2005). Percent accuracy was determined by recording the total score on each WPS probe divided by the total of sixteen possible points.

Social acceptability and utility. The perceived utility and social acceptability of the independent variable, was measured using the Children's Usage Rating Profile (CURP; Briesch & Chafouleas, 2009). The CURP is a self-report measure for students that assesses their perceptions of an intervention's desirability, understanding, and feasibility. A self-report was chosen because the students' own perceptions of the intervention can provide valuable information about whether it was appropriately responsive to their cultural and linguistic identities. The measure is written at a third grade reading level and the items were also read aloud to the students to increase likelihood of comprehension. There are 23 items that use a 4-point Likert scale (from 1= “total disagreement” to 4 = “total agreement”). The reliability of the CURP as measured by the internal consistency of each of the subscales ranges from 0.75 to 0.92 (Briesch & Chafouleas, 2009).

Experimental Condition

The CLR-SBI was adapted from Jitendra’s schema-based instruction curriculum (Jitendra, 2007). The curriculum was adapted to only include lessons on the change problems due to time restrictions. Intervention was delivered in small groups of 2 or 3 and throughout instruction interventionist led demonstration, modeling, and frequent student responses were used to facilitate learning.

SBI Change problems. Each lesson in the SBI curriculum begins with a two-minute warm up with flashcard practice to improve students’ computational fluency. The first lesson of the SBI condition teaches participants to solve change word problems through the use of teacher modeling (see Appendix A for the schematic diagram reproduced from Jitendra, 2007). Students were taught to identify the critical elements of the change situations: a beginning amount, a change amount, and an ending amount. They were also taught that the label or object for the beginning, change, and ending amount will all be the same. For the second step in the change problem checklist, students were taught to organize the story information by identifying the label for the three items of information and filling it in the diagram and then locating the quantities associated with the beginning, change, and ending amounts. Students were also taught that each problem has a missing element, which they should flag on their diagrams with a question mark. Interventionists instructed students on the semantic properties of the problems in order to determine the missing element.

The third step of the problem solution checklist includes transforming the information in the diagram into a number sentence. Students were taught to plan how they will solve the number sentence in step three as well. Finally, students were taught to solve for the unknown in the number sentence, write the complete answer including the label, and check their solution for appropriateness. Explicit feedback and additional modeling were used to address any misconceptions about problem schema constraints.

The second and third lesson in the change problem unit included guided practice with the interventionist facilitating problem solving by prompting frequent student exchanges. Lesson two and three also provided opportunities for independent practice with frequent corrective feedback. Students gained experience in these lessons completing problems with information from charts and pictographs as well as a range of story contexts. The final lesson provided instruction on fading the change diagram to facilitate efficient problem solving. Students were also encouraged to use the change problem solving checklist only as needed. The curriculum recommended three days to complete each of the four lessons for a total of twelve intervention sessions on change problems. The change lessons took 19 sessions for Group 1 to complete, 15 sessions for Group 2 to complete, and 10 sessions for Group 3 to complete for an average of 14.3 sessions.

Culturally and linguistically responsive SBI. The traditional SBI curriculum was adapted to incorporate culturally and linguistically responsive pedagogy in several ways (see Appendix E for the intervention protocol). First, oral discussion among peer student dyads was encouraged (Driver & Powell, 2017). Students were prompted to discuss with each other their responses throughout the problem solving process. This was incorporated during the practice sessions built into the traditional SBI curriculum. Students were instructed to work together to solve the practice problems at the end of each lesson. Second, students were encouraged to use Spanish in their discussions with one another (Driver & Powell, 2017). Spanish was presented as a resource to assist students in engaging in the problem solving process (García, 2009). The scripted protocol included a prompt to remind students that their Spanish could be used as a problem solving tool to help them work together to solve the problems. Third, students' experiences were incorporated and used to develop relevant instructional examples (Driver & Powell, 2017). At the end of each session, students were asked open ended questions about their experiences, lives, and pop culture (e.g., "What is your favorite book?" "What does your family like to eat?" "What are you going to do this weekend?"; see Appendix F for a list of experience questions). Their responses to these questions were used to develop word problems during the session, with input from students, for the students to then solve. For example, one student was asked about what their family likes to eat and so the interventionist and students came up with the word problem, "Katie had 6 tortillas. She gave 2 to her sister. How many tortillas does Katie have left to eat?"

Additional computation practice. After completion of all lessons on change problems as outlined in the SBI curriculum, the progress monitoring data for the first and second intervention groups showed common errors based on computation deficits. Because of this finding and the decision to include participants with computation difficulties, it was determined that additional computation practice was warranted prior to introducing a second word problem type. A cover-copy-compare intervention component (Skinner, 1997) which focused on double-digit addition and subtraction was added while continuing to incorporate flash card drills and word problem-solving practice of change type problems with culturally relevant teaching examples (see Appendix G for the computation practice adapted protocol).

Experimental Design

A multiple probe design across participant dyads was chosen to evaluate the efficacy of the CLR-SBI intervention. Because students received the intervention in pairs, each student group proceeded through the experiment in the same phase but his or her performance was graphed individually. With seven participants this resulted in three replications of the effect across student groups. This approach was utilized rather than averaging student performance across groups in order to examine individual student responsiveness to the intervention. In this design type, the probe or baseline condition is systematically lengthened across participants prior to the introduction of the intervention condition (Gast, Lloyd, & Ledford, 2014). In contrast to the multiple baseline design, the multiple probe design does not require continuous measurement of the behavior prior to the introduction of the treatment (Horner & Baer, 1978). This study consisted of three phases, (a) the probe phase which occurs prior to intervention implementation, (b) the intervention phase consisting of implementation of the CLR-SBI, and (c) the maintenance phase which occurred six weeks after the completion of the intervention phase. The probe phase will be referred to as the baseline phase in this study to increase intelligibility.

Data were initially collected concurrently for all participants every day for five days during the baseline phase because five is the smallest number required to meet What Works Clearinghouse standards (Kratochwill et al., 2010). In order to proceed to the intervention phase from the baseline phase, the following conditions were observed: (a) trend was stable, (b) level of performance remained between zero and 50% correct on the WPS probe, and (c) variability was low (Kratochwill et al., 2010). The participant group with the most stable performance after five probe sessions received the intervention first.

Data were collected three times per week during the intervention condition. Meanwhile for the participants still in the baseline condition, data were collected once per week. After all students in the first participant dyad showed an accelerating level of performance, the second participant group was moved into the intervention phase (Xin & Zhang, 2009). Similarly, after all students in the second participant group showed an accelerating level of performance, the third participant group was moved into the intervention phase. The intervention phase continued for each participant group until all of the change lessons in the CLR-SBI curriculum were completed in the last group. Six weeks after the completion of the intervention phase, one probe was given to assess maintenance of skills.

Visual analysis was used to evaluate the data paths for changes in level, trend, and variability. Each member of the participant groups has their data represented in their own graph. The functional relationship between the intervention condition and word problem solving performance is demonstrated by an immediate change in WPS performance upon introduction of the CLR-SBI while the WPS performance for the other participants remains stable (Gast et al., 2014).

Procedures

Survey level assessment. Following screening, a pool of all eligible participants was given six different subskill mastery measures: (a) single digit addition, (b) single digit subtraction, (c) double digit addition with regrouping, (d) double digit addition without regrouping, (e) double digit subtraction with regrouping, and (f) double digit subtraction without regrouping. Students were given each probe following standardized instructions sequentially starting with the easiest skill in the hierarchy to the hardest (Shapiro, 2011).

Baseline phase. During each baseline session students completed one adapted WPS probe. Participants had ten minutes (Jitendra, et al., 2005) to complete the eight change and compare problems. Interventionists read each problem out loud to the participants and allowed them to complete the problem before moving on to the next item.

Intervention phase. During the intervention condition, sessions occurred three times per week. Each session began with 20 minutes of CLR-SBI followed by the administration of the WPS probe for 10 minutes. At the end of each session, students received a small educationally relevant token (e.g., sticker, pencil, eraser) for participation. The interventionist recorded whether or not Spanish was spoken during the intervention session. After the last session of the intervention students were asked to complete the CURP for the Spanish enhanced SBI to assess social acceptability and utility.

Maintenance probe. Maintenance was assessed six weeks after intervention. One adapted WPS probe was presented following the same procedures as in the baseline and intervention conditions.

Treatment Integrity

Independent observers, who are graduate students in the educational psychology department, listened to audio recordings to assess treatment adherence. The observers used a checklist created from the intervention protocol (see Appendix E) to assess a random selection of 25% of each interventionist's sessions. The checklist had space to record whether each step in the intervention protocol was fully, partially, or not implemented. The percentage of adherence to the intervention script was computed by dividing the number of fully implemented steps by the number of total steps and multiplied by 100 to yield a percentage. The overall treatment integrity was 93%.

Inter-scorer Agreement

The independent observers also checked for interscorer agreement in 25% of the WPS probes. The graduate students all had two courses on assessment, which included instruction on CBM scoring and administration procedures. Additionally, the first author and graduate student independent observers scored one WPS probe and compared their levels of agreement until 95% agreement was achieved. Total percent agreement was found by dividing the total number of agreements by the number of agreements plus disagreements divided by 100. The total inter-scorer agreement was 99%.

CHAPTER 4

Results

This chapter will describe the study sample in regard to screening results, language survey results, and language usage during the intervention. In addition, findings will be presented associated with each of the three research questions. First, I will describe the performance of the sample of seven Spanish-speaking EL students on word problem solving probes compared to baseline condition. Second, I will examine the maintenance effects of word problem solving performance six weeks following intervention implementation. Third, I will describe the student perceptions of the culturally responsive schema-based instruction.

Descriptive Results

Screening. Table 3 provides screening data. The cutoff point for the AIMSweb M-CAP assessment was defined as students at or below the 25th percentile, which for second grade fell at 11 or fewer correct. The student participants in second grade scored between 3 and 9 on the M-CAP. For third grade students the 25th percentile fell at 7 or fewer correct. Both third grade participants scored 4 points on the M-CAP. Results of the survey level assessment showed that only the third-grade students were at the instructional level or above for single- and double-digit addition and subtraction. Three of the second-grade students were in the instructional level for single digit addition, and two were below instructional level. All second-grade students fell below the instructional level for single-digit subtraction and double-digit addition and subtraction.

Table 3

Participant Screening Results

Student	AIMSweb M-CAP	Single digit		Double digit without regrouping		Double digit with regrouping		WPS
		Addition	Subtraction	Addition	Subtraction	Addition	Subtraction	
Jorge	8	23	9	6	2	1	0	6.25%
Alexa	4	6	3	4	1	3	1	12.5%
Mia	3	12	8	10	10	2	0	12.5%
Julieta	9	20	10	9	3	6	2	12.5%
Oscar	6	16	6	9	3	6	0	12.5%
Diana	4	49	22	36	14	24	8	12.5%
Catalina	4	62	28	55	16	33	11	6.25%

Language survey. Table 4 presents results from the language use survey completed by the participants' classroom and English language teachers. Four general education teachers and four English language teachers were surveyed. Of the four general education teachers surveyed, two reported speaking only English and two reported speaking English with some Spanish during instruction. Of the four English language teachers surveyed, two reported speaking only English and two reported speaking English with some Spanish during instruction. Two general education teachers reported speaking only English during non-instructional time and two reported speaking mostly English with some Spanish. Three English language teachers reported speaking English only during non-instructional time, and one reported speaking mostly English with some Spanish. In regard to which language the teachers heard the students using during academic tasks, half of the teachers reported hearing the students use mostly English with some Spanish, 36% reported hearing only English, and 14% reported hearing equal amounts of English and Spanish. During non-academic time, half of the teachers reported hearing the students speaking mostly English with some Spanish, 14% reported hearing only English, 14% reported hearing equal amounts of Spanish and English, and 21% reported hearing mostly Spanish with some English.

Table 4

Language Use Survey Results

	Classroom Teachers				English Language Teachers			
Student	Teacher instruction	Teacher non-instruction	Student academic task	Student non-academic time	Teacher instruction	Teacher non-instruction	Student academic task	Student non-academic time
Jorge	English	English	English	English	English	English	English	Mostly English
Alexa	Mostly English	English	English	Mostly English	Mostly English	Mostly English	Mostly English	Mostly English
Mia	Mostly English	English	English	Mostly English	English	English	Mostly English	Mostly English
Julieta	Mostly English	Mostly English	Mostly English	Equal	Mostly English	English	Mostly English	Mostly English
Oscar	Mostly English	Mostly English	English	Mostly English	Mostly English	English	Mostly English	English
Diana	English	Mostly English	Equal	Mostly Spanish	English	English	Equal	Mostly Spanish
Catalina	English	English	Mostly English	Equal	English	English	Mostly English	Mostly Spanish

Teachers were also asked about their language use policies in their classroom. Three general education teachers reported that students' native language use was encouraged in their classrooms, and one reported that native language use was allowed in their classroom. Similarly, three English language teachers reported that students' native language use was encouraged in their classrooms, and one reported that native language use was allowed in their classroom. When asked about specific policies and practices, the English language teacher who reported that native language use was allowed but not encouraged wrote that she usually encourages English language use in her classroom. Another English language teacher who reported that native language use was encouraged wrote that she regularly uses parent volunteers who speak the native languages of her students in her lessons. Another English language teacher wrote that she uses native languages to aid in instruction by introducing cognates and reported that her students take pride in their native language abilities. Finally, one general education teacher wrote that she intentionally encourages native language use because it helps the students take pride in their identity.

All of the EL teachers, except for Jorge's teacher, heard the students speak at least some Spanish during academic tasks. However, only Julieta, Catalina, and Diana's classroom teachers heard them speak at least some Spanish during academic tasks. Therefore, more students were heard speaking Spanish in an academic context in the EL classroom than in the general education classroom. In addition, only Diana was reported to speak an equal amount of Spanish and English during academic tasks. These results show that all of the students except Jorge had some experience using Spanish in an academic context, and the opportunity to do so during the CLR-SBI intervention was not a novel experience for them.

Language usage. Interventionists recorded when Spanish was spoken during intervention sessions. Group 1 used Spanish in 8 out of 29 sessions. Spanish was used to clarify word problem contexts and to rephrase word problem solving instructions. Jorge preferred to use Spanish more than Alexa or Mia, but he would ask the other students in his group to tell him in Spanish, so they would use Spanish most often to translate instruction or word problems for him. Group 2 did not use Spanish in any of the 18 sessions. Spanish was used infrequently in this group and the students did not appear to be comfortable speaking Spanish. This group also engaged in the least amount of collaborative discussion in general. Group 3 used Spanish in 9 out of 10 sessions. These students used Spanish throughout problem solving to plan for how to solve the problems (e.g. “Tu vas a leer o yo?” “Are you going to read it or me?”). They worked collaboratively and used Spanish more frequently than English when they were working together.

Word Problem Solving Performance

Visual analysis was used to answer the first research question (i.e. Will culturally responsive schema-based instruction improve Spanish-speaking EL students’ performance on word problem solving probes compared to baseline condition?). Visual analysis was conducted by comparing the baseline and treatment phases according to level, trend, and variability. In addition, effect sizes were calculated using Tau when the baseline was stable and Baseline Corrected Tau, a non-parametric rank correlation effect size when there was a baseline trend (Tarlow, 2017). A decision tree was used to correct for baseline trends only when there was a statistically significant monotonic baseline trend. Effect sizes were calculated using an online calculator (http://www.ktarlow.com/stats/tau; Tarlow 2016). Student performance was not averaged across groups but was instead examined individually for each student. This was done because when data is averaged across groups individual variability is often masked (Gast et al., 2014). Jorge, Alexa, and Mia made up Group 1 (see Figure 1), Julieta and Oscar were in group 2 (see Figure 2), and Diana and Catalina were in Group 3 (see Figure 3). Word problem solving maintenance was measured six weeks following intervention.

Jorge. During the baseline phase, Jorge's performance was stable and low with an average 2.5% problems correct (*SD* = 3.42). Following intervention implementation, Jorge's performance remained low and stable until the fourth intervention session after which his performance then showed an increasing but variable trend which stabilized after the tenth intervention session (*Mean* = 23.61%, *SD* = 17.62). Jorge's performance with the CLR-SBI intervention yielded a moderate effect size (Tau = 0.46, $p = 0.016$, $SE_{Tau} = 0.26$). After the implementation of the modified CLR-SBI intervention with computation practice, Jorge's performance did not demonstrate a change in level, but continued to show an increasing trend (*Mean* = 50.00%, *SD* = 20.62). When an effect size was calculated including all intervention data points (i.e., CLR-SBI alone and CLR-SBI with computation practice), the effect size was moderate and slightly smaller than the CLR-SBI only effect size (Tau = 0.44, $p = 0.004$, $SE_{Tau} = 0.22$). Jorge's highest level of performance reached 75% problems correct. During follow-up, Jorge completed 37.5% problems correct, which was much higher than baseline, but lower than his performance at the end of the intervention phase.

Alexa. During the baseline phase, Alexa's performance was stable with an average score of 34.38% problems correct (*SD* = 6.25). Following intervention implementation, Alexa's performance demonstrated a decreasing trend until the fourth intervention session after which her performance showed a steep increasing trend which stabilized between 75% and 87.5% correct (*Mean* = 68.09%, *SD* = 20.61). Alexa's performance with the CLR-SBI intervention produced a moderate effect size (Tau = 0.49, *p* = 0.011, SE_{Tau} = 0.26). After the implementation of the modified CLR-SBI intervention with computation practice, Alexa's performance demonstrated a change in level and a stable trend between 87.5% and 100% problems correct (*Mean* = 94.44%, *SD* = 4.89). When an effect size was calculated including all intervention data points, the combined intervention produced a moderate effect size which was slightly smaller than the CLR-SBI only effect size (Tau = 0.45, *p* = 0.005, SE_{Tau} = 0.22). Alexa's highest level of performance reached 100% problems correct at the end of the intervention. During the maintenance check, Alexa completed 87.5% problems correct which was higher than baseline and consistent with performance during the intervention phase.

Mia. During the baseline phase, Mia's performance was stable and low with an average 6.25% problems correct (*SD* = 4.42). Following intervention implementation, Mia's performance demonstrated an increasing trend (*Mean* = 29.27%, *SD* = 17.56). Mia's performance with the CLR-SBI intervention yielded a moderate effect size (Tau = 0.49, *p* = 0.008, SE_{Tau} = 0.25). After the implementation of the modified CLR-SBI intervention with computation practice, Mia's performance did not demonstrate a change in level, but continued to show an increasing trend (*Mean* = 52.50%, *SD* = 13.57). When an effect size was calculated including all intervention data points, the combined intervention produced a moderate effect size which was slightly smaller than the CLR-SBI only effect size (Tau = 0.46, *p* = 0.002, SE_{Tau} = 0.22). Mia's highest level of performance reached 75% problems correct at the end of the intervention. During follow-up, Mia completed 62.5% problems correct which was much higher than baseline and consistent with the level of performance demonstrated at the end of the intervention phase.

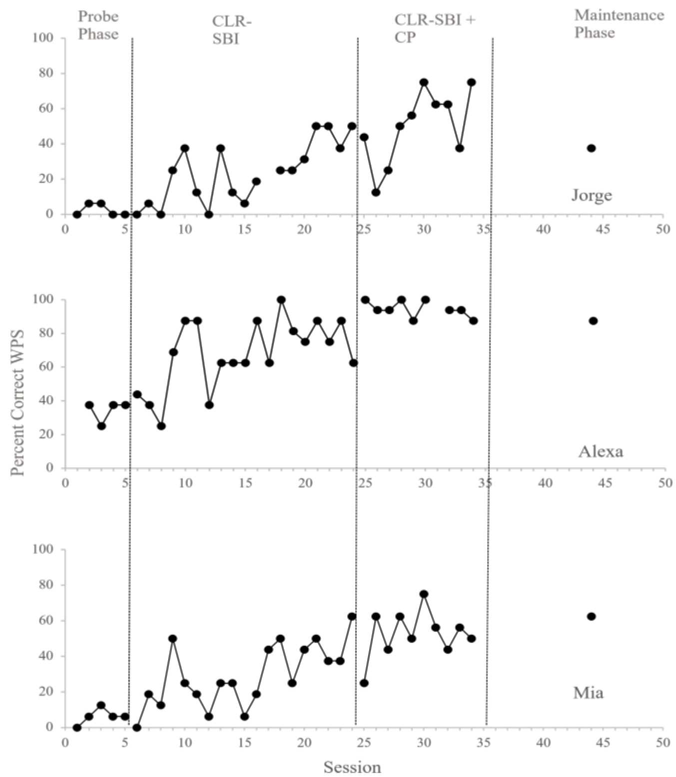

Figure 1. Word problem solving accuracy of Group 1.

Julieta. During the baseline phase, Julieta's performance was stable with an average 43.18% correct (*SD* = 8.04). Following intervention implementation, Julieta's performance demonstrated an increasing but variable trend (*Mean* = 69.58%, *SD* = 17.81). Julieta's performance with the CLR-SBI intervention yielded a moderate effect size (Tau = 0.59, $p = 0.001$, $SE_{Tau} = 0.22$). Julieta's highest level of performance reached 93.75% problems correct at the end of the intervention. Julieta missed the last week of the intervention condition because her family was traveling, and thus her maintenance probe was collected seven weeks after her last intervention session, and she did not participate in the modified CLR-SBI intervention with computation practice. During the maintenance check, Julieta completed 75% problems correct which was higher than baseline and consistent with the end of the intervention phase.

Oscar. During the baseline phase, Oscar's performance showed an increasing trend with an average 22.16% problems correct (*SD* = 7.58). Following intervention implementation, Oscar's performance demonstrated an immediate decrease in level followed by an increasing trend (*Mean* = 35.76%, *SD* = 13.86). Oscar's effect size was calculated using Baseline Corrected Tau to adjust for the increasing trend seen in the baseline phase; Oscar's variable performance with the CLR-SBI intervention yielded a moderate effect size in the unintended direction (Baseline Corrected Tau = -0.58, p = 0.001, SE_{Tau} = 0.23). After the implementation of the modified CLR-SBI intervention with computation practice, Oscar's performance did not demonstrate a change in level, but continued to show an increasing trend (*Mean* = 52.50%, *SD* = 13.57). When an effect size was calculated including all intervention data points, the combined intervention also produced a moderate effect size in the unintended direction which was slightly smaller than the CLR-SBI only effect size (Baseline Corrected Tau = -0.59, p = 0.000, SE_{Tau} = 0.21). His performance at the end of the intervention reached 62.5% problems correct compared to a maximum of 43.75% problems correct during baseline. Oscar completed 62.5% problems correct during the maintenance check which was higher than baseline and consistent with his performance at the end of the intervention phase.

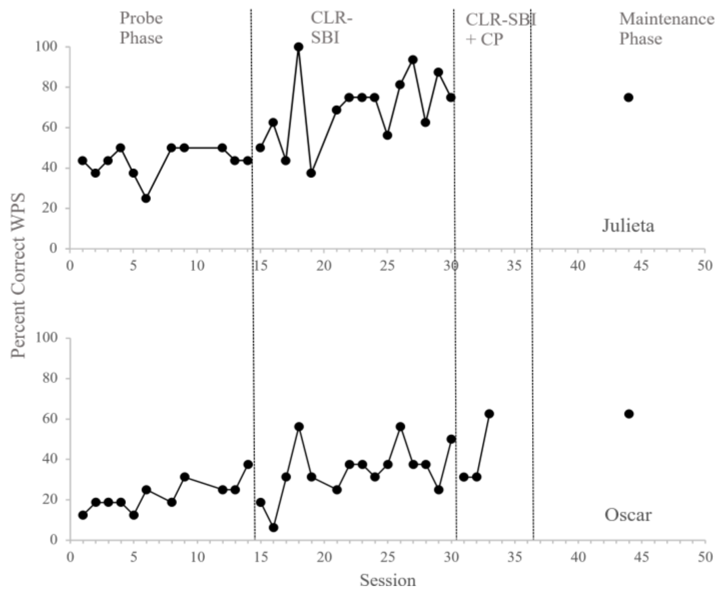

Figure 2. Word problem solving accuracy of Group 2.

Diana. During the baseline phase, Diana's performance was stable with an average 29.58% problems correct (*SD* = 6.87). Following intervention implementation, Diana's performance demonstrated an increasing but variable trend (*Mean* = 53.75%, *SD* = 20.03). Diana's performance during the CLR-SBI intervention yielded a moderate effect size (Tau = 0.56, $p = 0.002$, $SE_{\text{Tau}} = 0.24$). Diana's highest level of performance reached 87.5% problems correct during the intervention phase. During the maintenance check, Diana completed 62.5% problems correct which was higher than performance displayed during baseline and commensurate with her performance at the end of the intervention phase, although slightly lower than her highest performance level.

Catalina. During the baseline phase, Catalina's performance was stable with an average 27.08% problems correct (*SD* = 7.72). Following intervention implementation, Catalina's performance demonstrated an increasing trend (*Mean* = 45.62%, *SD* = 12.52). Catalina's performance during the CLR-SBI intervention yielded a moderate effect size (Tau = 0.60, $p = 0.001$, $SE_{\text{Tau}} = 0.23$). Catalina's highest level of performance reached

62.5% problems correct at the end of the intervention phase. During the maintenance check, Catalina completed 50% problems correct which was higher than baseline and commensurate with performance in the intervention phase, although slightly lower than her highest performance level during intervention.

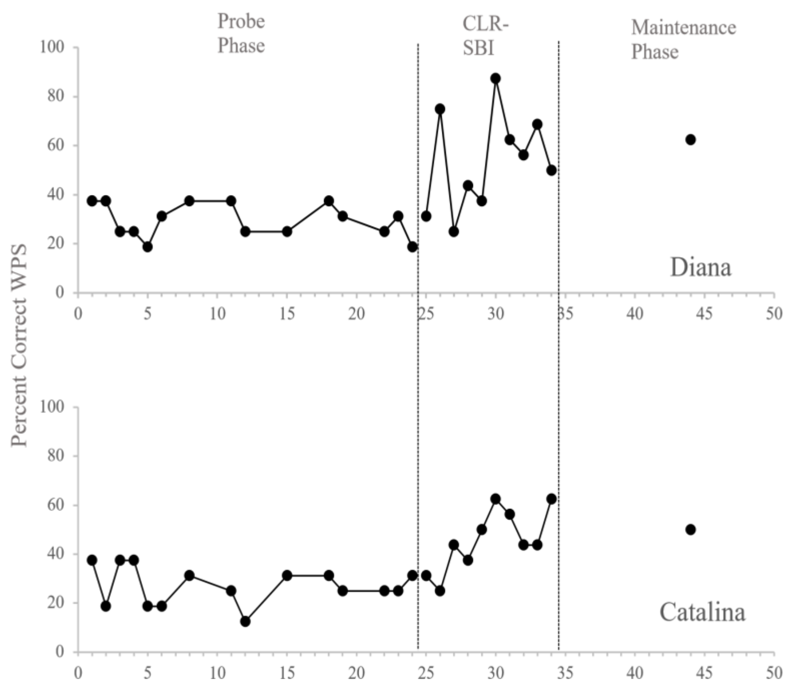

Figure 3. Word problem solving accuracy of Group 3.

Overall, the data across groups demonstrates a functional relationship between the CLR-SBI intervention and the word problem solving performance (see Figure 4). The data show six direct replications of the effect across students in all three groups with a clear change in trend between baseline and CLR-SBI intervention phases. There was no effect demonstrated for the modified CLR-SBI intervention with additional computation practice, as it was not implemented across all three groups, and there was no clear change in trend between intervention phases for the students who received the modified intervention. In addition, the data from this phase yielded effect sizes which were slightly smaller than the CLR-SBI only phase for all students.

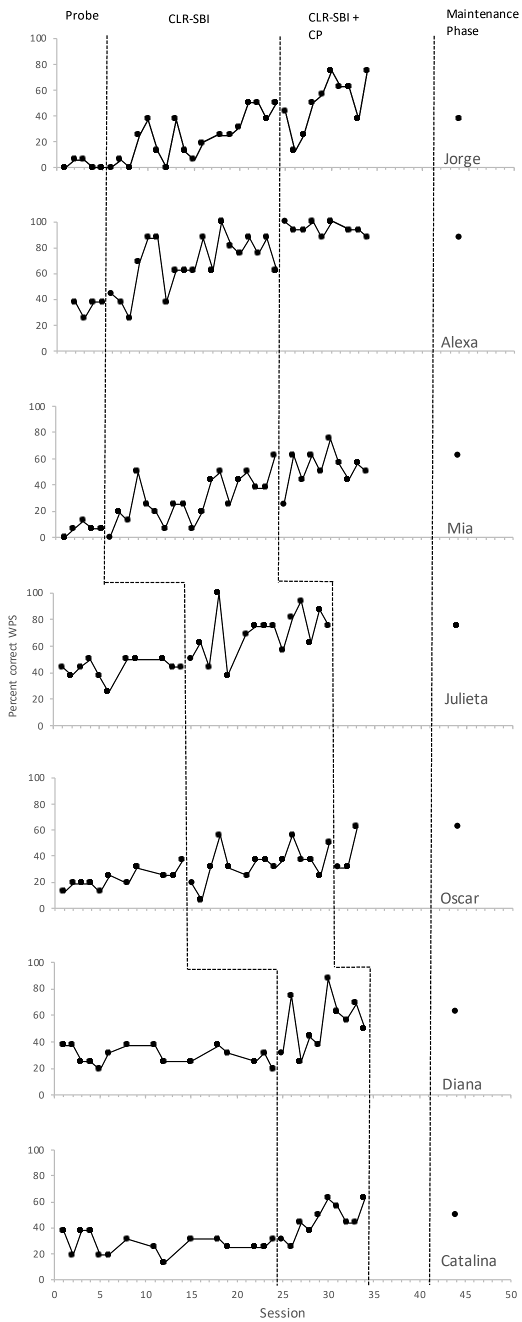

Figure 4. Word problem solving accuracy across groups.

Social Acceptability and Utility

Social acceptability and utility were measured using the Children's Usage Rating Profile (CURP; Briesch & Chafouleas, 2009) at the end of treatment. The CURP measures acceptability of an intervention across three dimensions, (a) personal acceptability/desirability, (b) feasibility, and (c) understanding. It is scored using a 4-point Likert scale with higher ratings indicating greater acceptability. The average CURP rating for the CLR-SBI was 3.48 (range 2.48 to 3.95) out of a possible 4 points for an overall 87% acceptability rating. Understanding was the highest rated dimension with an average score of 3.79 (95%, range 3 to 4), personal acceptability was second with an average score of 3.55 (89%, range 2.71 to 4), and feasibility was lowest with an average score of 3.20 (80%, range 1.88 to 3.88).

CHAPTER 5

Discussion

Despite the persistent mathematics achievement gap between English learners and their native-English speaking peers, there is a limited research base that targets the mathematics achievement of these students. Specifically, word-problem solving is an area within mathematics that particularly challenges EL students. The purpose of this study was to evaluate the effectiveness of culturally and linguistically responsive schema-based instruction (CLR-SBI) to improve the performance of mathematics word-problem solving in a sample of Spanish-speaking ELs. An evidence-based intervention that targets word problem solving skills, schema-based instruction, was adapted to integrate culturally and linguistically responsive approaches.

The following discussion will explore the descriptive language use results and implications. It will then present a discussion of the following research questions: (1) Does culturally responsive schema-based instruction improve Spanish-speaking EL students' performance on word problem solving probes compared to baseline condition?, (2) Are the effects of culturally responsive schema-based instruction on word problem solving performance maintained when measured six weeks following intervention implementation?, and (3) What are students' perceptions of culturally responsive schema-based instruction? Finally the study's limitations, implications, future directions, and conclusions will be presented.

Language Usage

Language use survey. In regard to what languages the teachers used with their students, more teachers reported speaking some Spanish during instruction than during non-instructional time. Thus, although this group of students had not been exposed to academic content instruction delivered primarily in Spanish, per teacher report, Spanish was sometimes present to aid instruction for half of the students. Due to the power dynamic between teachers and students, teachers' use of Spanish in instruction gives the students' native language a place of value within the educational context (Nieto, 2002). This may impact the level of comfort or familiarity the students had with Spanish being used in an academic context, and therefore the likelihood that they would engage in an intervention that incorporated Spanish.

Finally, the teachers were asked about language policies they had in their classrooms. A majority of the teachers reported that they encourage native language use in their classrooms. Several teachers reported intentionally expressing the value of students' native languages as an asset to the classroom and as a part of their identities. This shows that at least some of the teachers demonstrated sociolinguistic consciousness and awareness of the value of linguistic diversity, core orientations of linguistically responsive teaching (Lucas & Villegas, 2010).

Two of the teachers reported that they allow but do not encourage native language use in their classrooms, one of which wrote that she usually encourages students to speak in English during her class. These practices shift the linguistic value away from students' native languages, and positions English as the only language of value. In addition, these policies perpetuate the view of language diversity as a deficit rather than a resource (Nieto, 2002).

Language use during intervention. The students in Group 3 used Spanish most often during intervention (90% of the sessions). These students' teachers reported hearing them use Spanish during academic and non-academic tasks more often than most of the other students. In addition, these students' teachers reported that native language use was encouraged and valued in their classrooms. It is possible that these students had the most comfort speaking Spanish because they had been encouraged to use Spanish in an academic setting before. This group demonstrated a unique ability to engage in linguistically integrated group work and demonstrated translanguaging (i.e., a pedagogical approach that recognizes that all of students' languages are integrated and constantly active; MacSwan, 2017) strategies frequently while problem solving. These practices allow students to use their linguistic resources to support their conceptual understandings (García, 2009), and were thus encouraged during intervention sessions.

The students in Group 1 used Spanish occasionally (28% of the sessions) but did so much less frequently to aid their problem solving. Several of their teachers reported that native language use was allowed, but English was encouraged during academic tasks, which may explain why these students were observed to use Spanish infrequently during intervention sessions. These students used Spanish primarily for the purpose of translating story problem contexts. Palmer et al. (2014) advocate for positioning students as bilingually competent by affirming their developing abilities to translate for each other. Although the Spanish language use was much less frequent in this group, anecdotally the students appeared to take pride in knowing how to translate and would volunteer to help when encouraged to do so.

Finally, the students in Group 2 did not use Spanish in any of the sessions. Their teachers did not report any classroom policies that would suggest that Spanish was not valued, and these teachers reported that the students spoke mostly English with some Spanish during academic tasks in their classrooms. It is unclear what was impacting this group's willingness to use Spanish during the intervention sessions, despite the homogenous native language grouping and encouragement to use Spanish as a resource to aid with problem solving during each intervention session. Overall there were large group differences in the quantity of Spanish language use and in the qualitative ways in which it was used. There are many possible factors which may have contributed to these group differences such as classroom native language use policies, prior experiences using Spanish during academic tasks, language preferences, and Spanish language proficiency.

Word Problem Solving Performance

The first research question addressed the efficacy of the CLR-SBI intervention as measured by the change in word-problem solving accuracy between the baseline and intervention phase. All seven students demonstrated an increasing trend in word-problem solving accuracy during the implementation of CLR-SBI. Visual analysis shows that all but one student showed a clear change in trend between the baseline and intervention phases. Oscar demonstrated an increasing trend in the baseline phase, which continued during the intervention phase, however visual analysis does not demonstrate a clear change in his word-problem solving accuracy due to the intervention. Results of effect size analyses support this finding, with all students except for Oscar demonstrating a moderate Tau effect size between 0.46 and 0.60. Oscar's increasing trend during the baseline phase resulted in a statistically significant monotonic baseline trend, and therefore his effect size was calculated using the Baseline Corrected Tau, resulting in a negative effect size.

None of the students demonstrated an immediate change in level after the first intervention session. Most students showed an improvement after two or three sessions. The lack of immediacy of effect is most likely due to the number of sessions needed to complete the first lesson in the SBI manual (Jitendra, 2007). After the completion of the first lesson which includes several opportunities to practice, all students demonstrated a change in level and trend.

The intervention was modified for Group 1 and Group 2 to include computation acquisition support after the completion of all of the change word problem lessons. The traditional SBI manual includes computation fluency practice with flashcard warm up drills at the beginning of each lesson. However, the students in the present study were displaying computation errors that indicated a need for an acquisition intervention (Burns, Codding, Boice, & Lukito, 2010). After the addition of the cover-copy-compare intervention component, all students in Group 1 and Oscar from Group 2 (Julieta was absent all three days during this phase) showed a continuation of the increasing trend from the CLR-SBI phase. There was no clear difference in trend between intervention phases and there were similar effect sizes across intervention phases, so it is difficult to determine the added benefit of the additional computation practice. Computation is just one small component of the necessary pre-requisite skills associated with word problem solving (Codding et al., 2017), which may explain why the additional computation intervention component produced minimal added benefit. In addition, for Oscar in Group 2, this intervention phase only lasted three days, so the limited impact on his WPS performance could be partially explained by the length of the intervention phase.

Overall, results of this study suggest that the CLR-SBI intervention improved the word-problem solving performance of six out of seven students in this sample of Spanish-speaking EL students at-risk for MD. These findings support the previous work by Driver and Powell (2017) who found a significant pretest to posttest effect size of 0.79 after implementing a CLR schema intervention. In addition, this study furthers the work of Jitendra and colleagues on the effectiveness of SBI with a new population of students (e.g., Jitendra et al., 2013; Jitendra & Hoff, 1996). EL students have previously been included in participant samples (e.g., Jitendra et al, 2013) but few have reported effects separately for these students.

Word Problem Solving Maintenance

The second research question investigated the maintenance of intervention effects six weeks following implementation. All seven students in the present study demonstrated word-problem solving accuracy commensurate with their performance level during the intervention phase. In addition, all students showed a higher performance level on the maintenance probe than their median performance during the baseline phase. These results suggest that the students maintained their word-problem solving performance six weeks following the CLR-SBI intervention.

This finding extends the previous work by Driver and Powell (2017), who did not measure the maintenance of performance following their CLR schema intervention. Jitendra and colleagues (2007) investigated the immediate and maintained word-problem solving performance following the implementation of SBI for a subsample of students with a Learning Disability, EL, or receiving Title I services. They found that although this group of students who received the SBI intervention did not show a significant effect at post-test compared to a similar group of control students who received general strategy instruction on word problems, they did demonstrate a statistically significant effect size of 1.12 compared to the control group on a maintenance probe administered six weeks following instruction. Although the EL students in this study were analyzed together in a group with students with Learning Disabilities and receiving Title I services, it lends further evidence to support the maintained effectiveness of SBI for EL students.

Social Acceptability and Utility

The third research question addressed the social acceptability and utility of the CLR-SBI approach as measured by the Children's Usage Rating Profile (CURP; Briesch

& Chafouleas, 2009). Social acceptability and utility are important aspects to consider and measure when choosing and evaluating interventions for CLD students. The theory of culturally responsive teaching posits that when students' experiences and frames of reference are used to develop their academic knowledge, education is more personally meaningful and interesting (Gay, 2002). Educators need to develop an awareness of their students' attitudes towards instruction, so they can implement practices that increase these students' willingness to engage and learn.

The overall acceptability rating of the current study was 87%, demonstrating that the students generally understood, enjoyed, and felt they benefited from CLR-SBI. All students expressed positive attitudes towards the intervention group. These results support the social validity findings of the Driver and Powell (2017) study, which found that a majority of the students enjoyed the intervention and found it helpful. Together, this suggests that using CLR-SBI to target the mathematics word problem solving of ELs is a socially acceptable approach. Future research could also include additional questions or ratings comparing the different intervention components, as students tend to respond positively to interventions in general.

Limitations and Future Research Directions

One limitation of this study was the lack of immediacy of effect shown in the visual analysis of the word problem solving performance. However, due to the complexity involved in learning to solve word problems and the time it took to complete each SBI lesson, it would be expected that the data would show a gradual rather than immediate effect (Gast et al., 2014). In addition, frequent breaks due to planned (spring break) and unplanned (snow days) times off from school interrupted the intervention schedule. These breaks impacted Group 1 and Group 2 more than Group 3, as this group was still in the baseline phase during these interruptions. It is possible that these extended interruptions during intervention negatively impacted the rate of progress. However, these interruptions are realistic consequences of interventions in the school setting, and thus do not diminish the external validity of the results.

Another limitation of the study in regard to intervention dosage, is the proportion of time spent on progress monitoring using the adapted WPS probes. During each session the first 20 minutes was spent on intervention and the last 10 minutes was used for progress monitoring, thus one third of the allotted time was used for data collection. This was necessary in order to make appropriate research decisions in response to student performance, however it is not reflective of typical progress monitoring practices in a school setting. The SBI manual recommends an assessment after each problem type has been introduced (Jitendra, 2007). The additional time spent on progress monitoring meant the students received more sessions and therefore more opportunities to practice with culturally relevant teaching examples presented at the end of each session. Although this may have impacted the rate of progress, it may have also made the intervention more engaging and relevant to the students. Educators ought to consider the balance between the academic rigor of moving quickly through the content and providing additional time to engage in culturally relevant practices. Each of these addresses a separate criterion of culturally responsive pedagogy (Ladson-Billings, 1995), and both have value in a culturally and linguistically responsive academic intervention.

One potential solution to these methodological limitations is for future research to use randomized controlled trial (RCT) methodology to investigate the effectiveness of

CLR-SBI in comparison to a control group. This design type is seen as the gold standard in educational research and is robust to threats of internal validity (What Works Clearinghouse, 2014). An RCT would not be impacted by the lack of immediacy of effect or confounding variables such as breaks from school. It would also eliminate the need to measure progress every session, and therefore the intervention dosage could more accurately reflect typical intervention implementation.

Another limitation of the current study is the adaptations made to the dependent measure. The word problem solving probes used in this intervention were based on standardized WPS-CBM probes (Jitendra et al., 2005); however, they were modified in several ways to address the needs of the current study. The probes used in this study included only two of the three problem types, they did not include any multiple step problems, and additional items needed to be written to monitor progress more frequently. Reducing the number of problem types and eliminating multiple step problems should not have negatively impacted the reliability of the probes, although it may have impacted the predictive validity of the probes. The additional items that were written matched those from the original probes in regard to placement of the unknown and type of computation required (e.g., addition, subtraction, with or without regrouping), and only the surface contexts of the items were changed.

It is also important to note, that although change and group type problems were included in this study’s probes, students only received instruction on change type problems because of time constraints. So, although intervention performance during maintenance was at a similar level to intervention, few students demonstrated mastery on the CBM-WPS probes during the intervention or maintenance phase. This finding would be expected as students were only presented with instruction on half of the problem types present on the probes. Future research should investigate the effectiveness of CLR-SBI with all three addition and subtraction problem types, as the present study and the previous work by Driver and Powell (2017) only provided instruction on change problems due to time restraints. Future research may therefore require more total weeks of intervention, a higher frequency of intervention sessions per week, or longer intervention session times. The CLR-SBI approach could also be investigated with multiplication and division problems at the middle school level (e.g., Jitendra et al., 2009).

The positive results of the study, despite students only receiving instruction on one of the two problem types presented on the probes, suggest that some of the students were generalizing the skills learned during instruction on the change type problems to solve group problems. Similar results were found in Jitendra et al., (2002) with multiplication and division problems, and suggests that the conceptual understanding emphasized in SBI supports students in solving untrained word problem types. Future research should also investigate whether CLR-SBI will improve EL performance on state and district mandated assessments. Prior research found that SBI produced a significant difference in effect on the MAP mathematics achievement test compared to a control group (Jitendra et al., 2013), however this has yet to be investigated with EL students, or with a CLR approach.

Another limitation of the current study was that information on the students' Spanish language proficiency was not available; the school district in which the study was conducted does not collect native language proficiency data. Research has shown that bilingual students who are competent in their first and second languages tend to out-perform monolingual students on tests of mathematical achievement, while students with low proficiency in both languages performed lower than their monolingual peers (Clarkson, 1992). Future research is needed examine the interaction between students' Spanish and English language proficiencies and their response to CLR mathematics interventions.

Finally, this study was not able to address the value added of the CLR adaptations to the traditional SBI intervention in regard to student word problem solving performance, maintenance, or social acceptability or utility. It is unclear if the additional components made the intervention more effective or more acceptable to the students as there was no comparison group. Future research should investigate the relative effectiveness of SBI and CLR-SBI to test the hypothesis that when students are taught using their own lived experiences, information is learned more easily and thoroughly (Gay, 2002).

Implications for Research and Practice

The present study extends the literature on the effectiveness of schema-based instruction and replicates the findings of the Driver and Powell (2017) study investigating a culturally and linguistically responsive schema-based intervention. The present study used an experimental design that could attribute a functional relationship between CLR-SBI and the EL students' word problem solving performance. In addition, this study explored the language usage of each of the student groups. This study adds vital empirical evidence to the literature base on culturally and linguistically responsive practices, which tends to be more qualitative in nature (Morrison, et al., 2008). In addition, it adds evidence to suggest that SBI is an effective intervention with a new population of students.

The present study highlights CLR-SBI as a promising approach to instruction because of not only the efficacy of the intervention, but also the feasibility within the school setting. The additional CLR adaptations require minimal additional resources or expertise. Although the interventionists that implemented this approach were not fluent Spanish speakers, this approach shows that they can still promote the value of native language use in an academic setting by providing students opportunities to work with peers with the same native language, and providing encouragement of the value of native language use in the classroom. This allows for more flexibility for the interventionists, as bilingual teachers are a rare and valuable resource.

In addition to the support this study provides for the efficacy of the specific CLR-SBI approach, it also provides a model for adapting other interventions to increase their cultural and linguistic relevance. Providing extra opportunities for group work and encouraging native language use while problem solving are practices that are not specific to math word problem solving but could be incorporated into many academic interventions. Similarly, relevant teaching examples are possible in many academic contexts, require no additional resources, and greatly increase student engagement. Incorporating components such as these is vital in order to make instruction more congruent with the cultural and linguistic practices of diverse students (Gay, 2010).

Conclusion

This study was the first to use an experimental approach to examine the effectiveness of a CLR-SBI approach with Spanish speaking EL students with or at risk for MD. Overall, results indicate that the intervention was successful at improving and maintaining word problem solving performance with this sample. The students reported an overall positive attitude toward the intervention, providing evidence that they understood, enjoyed, and felt they benefited from CLR-SBI. This research adds valuable empirical evidence to a limited research base on mathematics interventions designed for ELs. It is recommended that future research will continue to investigate the key ingredients of the CLR-SBI approach, in order to better understand effective word problem solving approaches for these students, and how to eliminate the achievement gap demonstrated on state and national assessments.

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Appendix A

Visual Representations in Schema-Based Instruction

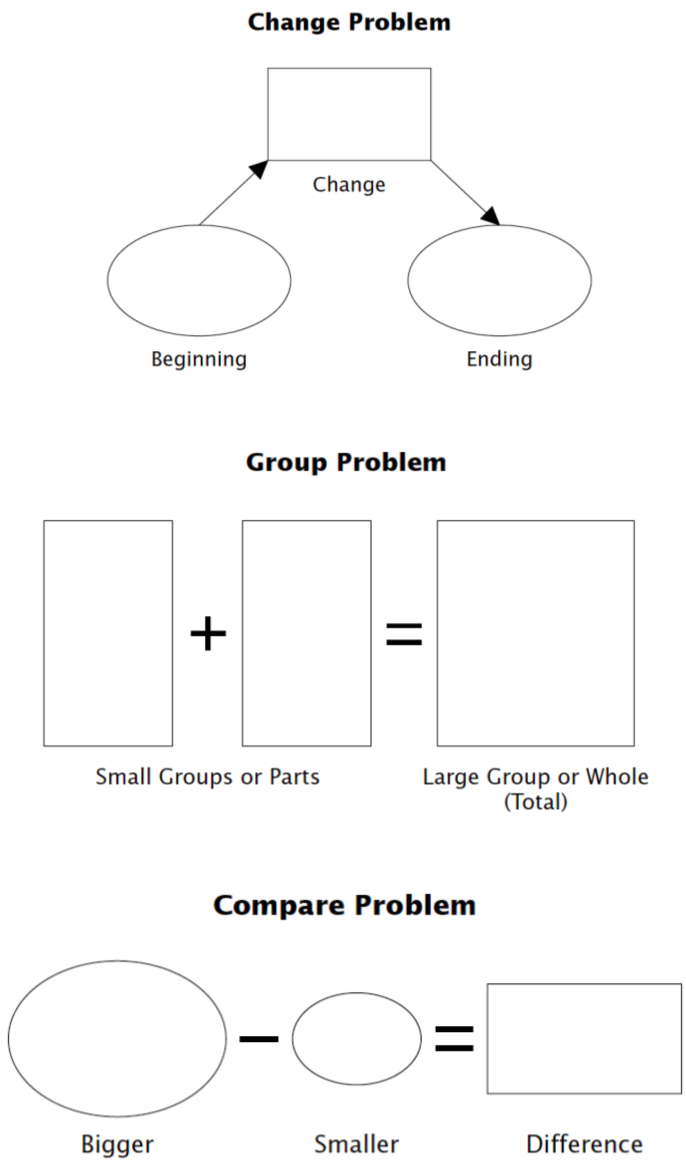

Figure A1. Change, group, and compare problem visual representations. Reprinted from *Solving Math Word Problems: Teaching Students with Learning Disabilities Using Schema-Based Instruction*, by A. K. Jitendra, 2007, Austin, TX: ProEd.

Appendix B

Parent Consent Form

University of Minnesota, School Psychology Research Study

Parent Consent Form for Child Participation

Research Study Title: Culturally and Linguistically Responsive Mathematics Word Problem Solving with English Learners

Researchers: The student investigator is Leila Jones, a doctoral student in school psychology at the University of Minnesota. Her faculty adviser and research supervisor is Dr. Robin Codding, an associate school psychology professor at the University of Minnesota.

Why is my child being invited to participate in this study?
Your child is being invited to participate because he or she is in the 2nd or 3rd grade and may benefit from help learning how to solve mathematics word problems.

What should I know about being in a research study?

- Someone will explain this research study to you.
- Whether or not your child takes part is up to you and your child.
- You can choose not to have your child take part.
- You can agree to take part and later change your mind.
- Your decision will not be held against you.
- You can ask all the questions you want before you decide.

Who can I ask my questions to about this study?
If you have any questions or would like additional information about this study, please contact:

Researcher	Email	Phone Number
Leila Jones	jone2880@umn.edu	(952) 240-0687
Dr. Robin Codding	rcodding@umn.edu	(612) 625-8656

This research has been reviewed and approved by an Institutional Review Board (IRB) within the Human Research Protections Program (HRPP). To share feedback privately with the HRPP about your or your child's research experience, call the Research Participants' Advocate Line at 612-625-1650 or go to www.irb.umn.edu/report.html. You are encouraged to contact the HRPP if:

- Your questions, concerns, or complaints are not being answered by the research team.
- You cannot reach the research team or you want to talk to someone besides the research team.
- You have questions about your or your child's rights as a research participant or you want to get information or provide input about this research.

Why is this research being conducted?

This research is being conducted to evaluate a program for improving performance on mathematics word problems. An intervention that targets math word problem solving skills will be adapted modified to include culturally and linguistically responsive approaches.

How long will the study last?
The study will last a total of 7-8 weeks. The first week of the study will be pre-testing with your child. The remaining weeks will take place during summer school and will be word problem solving instruction delivered to pairs of students 4 times a week for about 30 minutes a session.

How many children will participate in this research study?
We expect six students will participate in this research study and receive instruction time in pairs with the academic interventionist.

What happens if I do *not* want my child to participate in this research study?
You and your child may decline to participate in this research. If you do not want your child to participate, simply do not return this form. This will indicate to us that you *do not* grant permission for your child to receive the math intervention. If you decide that you do not want your child to participate in this project after the study has begun, contact the researchers and request your child be removed from the study.

What happens if I *do* want my child to participate in this research study?
If you do want your child to participate in the research study, please return this form with your signature indicating that you *do* grant permission for your child to receive the math intervention sessions.

Are there any risks for my child if they agree to participate in this research study?
It is possible that your child will be asked to leave a different, perhaps preferred, activity in the classroom in order to participate in instruction with the academic interventionist. To reduce this risk, we make the lessons as enjoyable as possible. The interventionist will provide verbal praise and feedback to your child in order to encourage them to continue doing their best. We will also provide small prizes (such as pencils, erasers, or other small trinkets) throughout the study in order to thank your child for his or her engagement. All data collected as part of this study will be securely stored in accordance with the University of Minnesota's data security recommendations, and any data used for dissemination purposes will be de-identified. Additionally, any electronic data collected that includes your child's name will be password protected, and only members of the research team, the child's teacher, and the child's parents will be granted access to this information.

If you want your child to participate in this research study, please sign below and return this form to Zanewood Community School. It may be dropped off to your child's classroom teacher.

☐ **I grant permission for my child to participate in this research study.**

Child's name:

____

Parent signature: ____ Date: _________________

The researcher may audio record the math practice sessions to ensure that the academic intervention is being delivered properly. Only members of the research team will have access to these recordings.

☐ **I grant permission for my child's math sessions to be recorded for intervention fidelity purposes.**

Parent signature: ____
Date:________________

Appendix C

Student Assent Script

University of Minnesota, School Psychology Research Study

Student Verbal Assent Form

Research Study Title: Culturally and Linguistically Responsive Mathematics Word Problem Solving with English Learners

Researchers: The student investigator is Leila Jones, a doctoral student in school psychology at the University of Minnesota. Her faculty adviser and research supervisor is Dr. Robin Codding, an associate school psychology professor at the University of Minnesota.

Text in blue is to be read aloud to potential participant:

Introduction
Hi, my name is Leila, and I am a graduate student at the University of Minnesota. I'm going to tell you about a research study I'm working on, and you will get to decide if you want to be a part of it or not.

Research study purpose
The purpose of my research project is to learn how to teach math word problem solving to students. We want to know if this math program is a good way to help students learn to solve math word problems. We hope that this program will help, but we won't know if it does until we try it.

Participants' role
If you want to be a part of my project, it means we would get to work together three times a week on math word problems. It would take about thirty minutes each time every Tuesday, Wednesday, and Thursday.

Voluntary nature
Your parent and teacher both said it would be okay for you to work with me, so now you get to choose if you would like to be a part of this project. It is completely up to you whether or not you want to participate. No one will be mad at you either way. If you decide now to be a part of the study, but then change your mind later and decide you don't want to do it, that is completely okay and your decision will be respected. If you get too tired during one of our lessons and want to stop, you can always tell me, and I'll stop the lesson and bring you back to class.

Do you have any questions?

To be completed by person obtaining verbal assent from the participant:

Child's/Participant's Name: ___________________________________

Child's/Participant's Response: ______yes _______no

By signing below, I acknowledge that the child/participant is capable providing assent to
participate.

____

Name of Person Obtaining Consent: ___________________________________

Appendix D

Word Problem Solving Probe Sample

Name:__________________________ Date: _________________

DIRECTIONS: Solve each word problem on the test and SHOW YOUR WORK by writing the number sentence and answer for each problem. You may use a diagram if it helps you solve the problems.

1. Some students took the bus to go home. At the first stop, 15 students got off. Now there are 18 students on the bus. How many students were on the bus in the beginning?

2. 12 Children attended Melissa's party. There were 7 boys. How many girls were there?

3. Jimmie has 17 red pens and 28 blue pens. How many pens does he have?

4. A scout troop leader is taking 14 scouts to the movies. Three scouts cancelled. How many scouts are going to the movie now?

5. There are 48 seats in the lower part of the stadium and 26 seats in the upper part of the stadium. How many seats are there in the stadium?

6. Jeremy had some pennies. He earned 8 cents. When he counted all of his pennies he had 17 cents. How many pennies did he begin with?

7. A piano has 52 white keys and 36 black keys. How many keys are there?

8. There are 12 children playing in a park. If 7 go home, how many children are left in the park?

Appendix E

Culturally and Linguistically Responsive Schema-Based Instruction

Materials

❑ SBI Protocol ❑ Laminated Change Story Checklist ❑ Packet of Student Pages ❑ Stopwatch ❑ Change Problem Probe ❑ Pencils or Pens ❑ List of experience questions ❑ Blank practice problem worksheet ❑ Small reward

Procedures

❑ 1. Say to the students, "**Hi Everyone! We are going to work together on practicing math word problems each week. This will be your packet. We are going to be working on change problems today."**

❑ 2. Follow script as outlined in SBI Protocol for 15 minutes.

❑ 3. After 15 minutes say, **"Today we learned about _____________. Tomorrow we will continue with _____________ and learn ____________________. We will finish for today with a math problem about your life."** Fill in the blanks with appropriate next steps based on how far you got in the current lesson. Ask a question from list of experience questions and develop a change problem using that information with help from the students. Remind students that they may use Spanish when working together.

❑ 4. Collect packet of student pages and all other instructional materials.

❑ 4. **Now, you will be taking a word problem-solving test. This test has 8 word problems. You will have 10 minutes to take this test.** (Pass out the test to student)

❑ 5. **As soon as I give you the test, write your name on the first sheet of your test** (Demonstrate). **After you have done this, turn over your paper and put your pencil down so I'll know you are ready** (Monitor students).

❑ 6. **I want you to do as many word problems as you can. It is okay if you cannot answer some of these problems, but I want you to do your best and solve as many problems as you can. I will read each problem on the test. After I read the problem, I want you to solve the problem. Show your work** (e.g., number sentence) **for each problem** (Point to the work space). **You may draw a diagram or picture if it helps you solve the problem. Then, write the complete answer on the line** (Demonstrate). **If you finish early, check your answer.**

❑ 7. **Let's start with the first problem** (Have student point to the first problem and you read aloud the problem). **Now, solve this problem.** (Allow 1 to 1 1⁄2 minutes for students to solve each problem, before moving to the next problem.) If students finish early remind them they should check for complete answers and then sit quietly and draw until time is up.

❑ 8. After ***10 minutes*** stop the stopwatch and say, **"Please stop. Put your pencil in the air so I can see you are done. (**pause**) Very good!**

❑ 9. Collect the test and say, "**Great work today. I like how well you listened to directions and worked hard."** Allow students to pick their reward from the prize box on the final session of each week.

Appendix F

Experience Questions

1. How many siblings do you have and what are their names?
2. What do you like to do with your siblings (or other family) at home?
3. What is your favorite holiday to celebrate? What do you do to celebrate this holiday?
4. What traditions does your family practice?
5. What do you like to do for your birthday?
6. What do you like to do in your free time?
7. What do you and your family like to do in the winter?
8. What do you and your family like to do in the summer?
9. What's your favorite sport or afterschool activity?
10. Do you like to watch sports on TV? What do you watch?
11. What do you like to watch on TV?
12. What's something you and your family do together?
13. What places do you like to visit?
14. What are you most thankful for?
15. What is your favorite food?
16. What food does your family love to cook?
17. What music do you like to listen to?
18. What are you going to do this weekend?
19. What toys do you like to play with?
20. What's your favorite treat?
21. What games do you like to play?
22. What is your favorite book?

Appendix G

Culturally and Linguistically Responsive Schema-Based Instruction with Computation Practice

Materials

❑ Flashcards ❑ Cover-copy-compare worksheet ❑ Laminated Change Story Checklist ❑ Stopwatch ❑ Change Problem Probe ❑ Pencils or Pens ❑ List of experience questions ❑ Blank practice problem worksheet ❑ Small reward

Procedures

❑ 1. Say to the students, "**Hi Everyone! We are going to work together on practicing math word problems each week. We are going to be working on change problems today.**"

❑ 2. Implement flashcard drill for 5 minutes.

❑ 3. Provide explicit instruction and modeling on multi-digit addition or subtraction.

❑ 4. Demonstrate cover-copy-compare practice.

❑ 3. No later than 3:30 say, **"We will finish for today with a math problem about your life."** Ask a question from list of experience questions and develop a change problem using that information with help from the students. Remind students that they may use Spanish when working together. Complete another practice problem if time allows.

❑ 4. Collect all instructional materials.

❑ 4. **Now, you will be taking a word problem-solving test. This test has 8 word problems. You will have 10 minutes to take this test.** (Pass out the test to student)

❑ 5. **As soon as I give you the test, write your name on the first sheet of your test** (Demonstrate). **After you have done this, turn over your paper and put your pencil down so I'll know you are ready** (Monitor students).

❑ 6. **I want you to do as many word problems as you can. It is okay if you cannot answer some of these problems, but I want you to do your best and solve as many problems as you can. I will read each problem on the test. After I read the problem, I want you to solve the problem. Show your work** (e.g., number sentence) **for each problem** (Point to the work space). **You may draw a diagram or picture if it helps you solve the problem. Then, write the complete answer on the line** (Demonstrate). **If you finish early, check your answer.**

❑ 7. **Let's start with the first problem** (Have student point to the first problem and you read aloud the problem). **Now, solve this problem.** (Allow 1 to 1 1⁄2 minutes for students to solve each problem, before moving to the next problem.) If students finish early remind them they should check for complete answers and then sit quietly and draw until time is up.

❑ 8. After ***<u>10 minutes</u>*** stop the stopwatch and say, **“Please stop. Put your pencil in the air so I can see you are done. (**pause**) Very good!**

❑ 9. Collect the test and say, “**Great work today. I like how well you listened to directions and worked hard.”** Allow students to pick their reward from the prize box on the final session of each week.