2022

ELL Mathematics: Best Practice and Methodology

Zach E. Holman
Bethel University

ELL MATHEMATICS: BEST PRACTICE AND METHODOLOGY

A MASTER'S THESIS

SUBMITTED TO THE FACULTY

OF BETHEL UNIVERSITY

BY

ZACH HOLMAN

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

MASTER OF ARTS IN EDUCATION

OCTOBER 2022

BETHEL UNIVERSITY

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Zach Holman

October 2022

APPROVED

Thesis Advisor: Nathan Elliott, M.A.

Program Director: Lisa M. Silmser, Ed.D.

Abstract

Math performance for ELL students continues to lag behind that of their native-speaking counterparts. While researching best practice when teaching ELL math, I found that many ELL students do not have equal opportunities when it comes to math. Many ELL students are placed in a math classroom that is below grade-level. In addition to misplacement, many ELL students do not receive adequate vocabulary and English support within the subject of mathematics, especially when attempting multi-step problems or word problems. Accelerating the learning of ELL students by providing interventions and advanced material helped improve achievement. In addition, emphasizing vocabulary while leveraging native language knowledge helps ELL students contextualize and master academic vocabulary. Many of the issues ELL students face in mathematics stem from a lack of vocabulary or academic language knowledge rather than difficulty with computation or mathematical skills. Finally, promoting self-efficacy and metacognition positively impacted ELL math achievement.

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CHAPTER I: INTRODUCTION

Context

Research and best practice for EL students has evolved greatly since the civil rights law addressing equal opportunity for ELs was enacted in 1970. Although research has been conducted on EL achievement, overall academic growth continues to lag behind that of native speaking students, according to the U.S. Department of Education (U.S. Department of Education, 2017). Based on what articles and studies I found regarding EL math achievement and practices, research has been conducted on validating the effectiveness of intervention strategies, the importance of vocabulary acquisition, and strategies for increasing self-efficacy.

Validation

Most of the studies I found that were conducted concerning the effectiveness of intervention or unique strategies for EL students learning math used a pretest and posttest format. The general consensus seems to be measuring effectiveness via accuracy on math problems, especially word problems. Typically, researchers sought to improve achievement via pull-out methods or specific differentiation methods within the classroom. The discussion around this topic has generally evolved from justifying the need for alternative strategies to the best practice and methods of implementation. These types of studies sought to show that using these methods would work in order to improve achievement but did not necessarily delve deeply into the specific strategies.

Vocabulary Emphasis

More recently, there has been an increased focus on researching the impact of vocabulary acquisition on math achievement. Historically there was a notion that math was a "universal language" and therefore needed less strategy and support for EL students (Li, 2016). Recent research suggests that is not the case, and vocabulary is just as important in math as any other subject. In addition to vocabulary words directly related to math, many academic words within problems cause issues for EL students, as they have multiple meanings in English depending on context (Janzen, 2008). The research indicates that best practice includes directly teaching math vocabulary to EL students.

Self-Efficacy

EL students are disproportionately placed in math classes that are below grade level (Martiniello, 2008; Thompson, 2017; Umansky, 2016). The reason for the poor placement stems from inequitable testing strategies, a high frequency of repeating students, and a lack of screening for new students. The tracking of EL students in math classes below grade level also has the unintended consequence of limiting growth, as many well-intentioned educators have historically provided EL students with insufficient challenges (Athanases & de Oliveira, 2014). Research has been conducted in order to investigate how much support to give to EL students, and which types of support are most effective. There has also been parallel and overlapping research that indicates the importance of self-efficacy and metacognition in determining math achievement. The difficulty lies in finding a balance between providing support for EL students and ensuring that they are sufficiently challenged in a way that supports their educational independence. Through my research, I found that self-efficacy and metacognition strategies were both effective in increasing EL student achievement.

Theoretical Framework

One integral theory used in this paper is the importance of metacognition in higher-level mathematical thinking. Metacognition is the ability to identify and reflect upon one's own thinking process. Through metacognition, students are more effective at selecting appropriate strategies, identifying strengths and weaknesses, and successfully processing high-level math problems. Using this framework, I sought to investigate how to help EL students acquire this skill while being able to accurately think about and communicate complex processes entirely in English. Although at first I was under the assumption that students should focus entirely on their English communication, through research I found that leveraging native language proficiency actually increases second language mastery.

Rationale

Achievement for EL students continues to lag behind native English speakers, and according to the U.S. department of education, nearly half of all states experienced a decrease in math proficiency for EL students in grade four. In 2016 the national graduation rate was 84 percent; however for EL students the graduation rate was 67 percent (U.S. Department of Education, 2017). This evidence shows that across the country, in general, EL students are achieving at a lower rate than their native English-speaking counterparts. This issue is pressing because multiple studies have indicated that the number of EL students is expected to continue to rise (Ardasheva, Tretter, & Kinny, 2012; Fayon, Goff, & Duranczyk, 2010; Herbert, 2012). As more EL students continue to join our school districts, said school districts will have to adapt and reinforce their EL strategies in order to teach all students with efficacy and equity.

In addition, I am focusing on math specifically because of the general feeling among educators who view mathematics as a “universal language” (Li, 2016). Neglecting the importance of vocabulary and language acquisition in the subject of mathematics would do nothing to close the gap in achievement between EL students and native speaking students. In fact, many of the studies included in this paper suggest the opposite; emphasizing vocabulary is essential to mathematical growth in EL students.

Math achievement is a strong indicator of academic success and high school graduation, which can have long-lasting impacts on a student's life. According to the U.S. Bureau of Labor Statistics, earning a high school diploma provides students with a wider variety of employment opportunities as well as an increase in average salary. In addition, median salary increases with post-secondary education, and unemployment drops with more education (Torpey, 2019). A shift in practices toward EL math students is necessary for not only their academic success but also for their post-secondary endeavors. By failing to provide an equitable education to our EL students, the education system is failing to provide equal opportunity to successful and fulfilling career paths for those students. It is the legal and moral obligation of our national and local educational institutions to provide equitable opportunities for EL students.

Definition of Terms

In this paper, "EL students" will refer to English Learner students. These are students who do not speak English as their first language. The term "intervention" has many meanings and specific types depending on the context of each classroom. In this paper, I will use "intervention" to mean a strategy used in the classroom directed towards EL students that would not have been implemented in an all native-speaking classroom. I will also use "intervention" when referring to a program that removes students from the classroom setting as an individual or in a small group in order to work on specific skills. In this paper, the term "math difficulties" will refer to a student who struggles with computational processes in the subject of math, specifically unrelated to language. The term "scaffolding" refers to a series of support systems for students that can be slowly removed as mastery increases. In this paper, the term "acceleration" will refer to teaching content that is above the students' current grade level understanding. In this paper, the term "metacognition" will be defined as being aware of one's mental processing.

Research Focus

There is a vast pool of EL research that has been conducted, but I wanted to focus on EL math achievement and the skills required to increase EL math achievement. I initially narrowed my focus by excluding any research that did not pertain directly to EL math. After reviewing what skills and strategies were researched and found to be effective for EL math, I broadened my research to include studies that focused on those specific skills in EL students. For example, I found multiple studies that discovered a correlation between self-efficacy and math achievement for EL students, so I broadened my research to include increasing self-efficacy in EL students. Similarly, I found a strong connection between vocabulary acquisition and math achievement, so I included research related to math vocabulary. Every branch of my research was either directly related to EL math achievement or directly related to a specific conclusion from an EL math study. I excluded research that focused on aspects of STEM outside of mathematics.

Through research and synthesis, I sought to answer the following research questions: What strategies are effective in increasing math achievement for EL students? What are the most effective ways of implementing those strategies? After conducting some research and discovering a few common trends, I added the following questions: How can educators increase metacognition for EL students? How can educators increase self-confidence and self-efficacy in EL students? When the research brought me to these questions, I was careful to only include results that directly related to an aspect of previous research. For example, multiple studies concluded that self-efficacy and metacognition were indicators of success for EL students in math. As a result, I sought out research on how to increase metacognition for EL students because it would also increase math achievement. I excluded studies related to metacognition that did not directly apply to either math achievement or second language acquisition.

CHAPTER II: LITERATURE REVIEW

Chapter II reviews the published literature on EL students, and more specifically, research on EL students in a math classroom. This chapter will review the purposes and needs for EL-focused math instruction and interventions, the impacts of emphasizing vocabulary in the context of math, and how to support EL students toward independent learning and metacognition. The literature review should help in determining best-practice for teaching math to EL students, as well as justify the need for math-specific EL strategy implementation. The literature I reviewed was found on ERIC, Academic Search Premier, EBSCO, and Google Scholar while using the following keywords: “english language math”, “math vocabulary”, “multilingual math”, “english language metacognition”, and “math metacognition”.

Justification for EL Math Intervention

There is a common misconception in education that math is a “universal language” and that many EL students may struggle with reading and writing, but they excel in math (Li, 2016). This statement implies that literacy is separate from other content areas, but learners need to be able to speak, think, listen, and understand mathematically. The previous statement regarding ELL students also indicates a misconception that math is universal, but any slight change in language can alter the entire meaning of a math concept. It is vital that teachers emphasize literacy in ELL math classes rather than treating math as a universal language. If students are not able to access the appropriate tools in order to participate in discourse, their vocabulary and literacy will not have the opportunity to develop. This section will discuss evidence for the necessity of EL-focused math instruction below.

Secondary mathematics is often viewed as a predictor for success in post-secondary education. In many cases, it can be a stopping point for students who might otherwise have been able to enroll in a post-secondary school. This hurdle can be especially difficult for EL students, who are far more likely to repeat a secondary math class according to a mixed method study conducted by Thompson (2017). Thompson set out to investigate the successful completion rate of high school math courses among EL students, as well as investigate the perspectives of the EL students who enrolled in those courses. The main purpose of the study was to figure out what is causing EL students to fail or repeat classes at a higher rate than their non EL contemporaries. This study was conducted across six California public school districts. Four cohorts of students who were enrolled in the sample districts in 7th to 10th grades from 2005–2006 through 2011–2012 (N = 11,966). For the qualitative data, Thompson used case study data consisting of interviews, notes, and school records of 14 EL students from a different California district.

The results of the study showed that EL students are significantly underperforming in secondary math classes. EL students are three to four times less likely to attain proficiency in Algebra 1, and are equally less likely to enroll in an accelerated math course (Thompson, 2017). In addition, EL students are proportionately more likely to repeat a secondary math course, and are less likely to show improvement when repeating a course compared to non-ELL students (Thompson, 2017). Thompson (2017) also found that EL students are around 25% less likely to be enrolled in Algebra 1 in 8th grade, which is a predictor for accelerated math courses in high school.

In addition to the quantitative data, Thompson gathered qualitative data to dig deeper into the perspectives of the EL students who had gone through the system in California. Based on interviews with former EL students, placement in lower-level math classes caused students to struggle to catch up in order to meet the graduation requirements. Students also reported that participating in mainstream classrooms that were not designed for ELs impacted their self-confidence. On a related note, the students also reported that they valued equitable social opportunities and individualized opportunities for support from educators (Thompson, 2017). The low grades earned negatively impacted their self-image and shifted their motivation for good grades towards motivation for simply earning the required credits in order to graduate.

The results of this study by Thompson indicate that only providing the opportunity to learn is necessary but not sufficient. School response to struggling EL students often does not facilitate learning. From the experiences of the EL students, Thompson concluded that they value personalization and context and easily feel left behind in the system. The evidence that nearly half of 8th-grade students had to repeat Algebra indicates that there needs to be more structural support for accelerated learning, especially for EL students.

In a related study, Umansky (2016) set out to examine the characteristics of EL students' access to grade-level academics in middle school. They used empirical data in order to analyze course placement for middle school EL students and what factors contributed towards limited course access for ELs. Umansky also offers an analysis of differences between subgroups of EL students in addition to the differences between EL and non-EL students. The data for this study was taken from a ten-year period spanning 2002 to 2012, from a large California district that annually enrolls between 60,000 and 70,000 students. Over half of the student population in this district speaks a language other than English at home (Umansky, 2016). The students in the study come from a variety of linguistic and national backgrounds. After reviewing all the class records of the students over that time period, a sample of 42,790 individual students and 189,013 student-semester observations in Grades 6–8 was collected.

As Umansky (2016) hypothesized, EL students were less likely to be enrolled in math, science, and language arts compared to non-ELL students. For math and science, 3% and 9% of

EL students were not enrolled, respectively. The results are worse for Language Arts classes, as 42% of ELs were not enrolled in Language Arts as compared to 2% of non-ELL students (Umansky, 2016). In many cases, English Language Development classes and English Language Arts were used as substitutes instead of compliments to each other. 32% of EL students were not enrolled in ELD, which goes against state and district policy (Umansky, 2016). When synthesizing data for an entire schedule of an EL student, only 53% of EL students were enrolled in a math, science, and language arts class in a given semester. The same analysis for non-ELL students shows that 95% of non-ELs were enrolled in math, science, and language arts (Umansky, 2016). This means that nearly half of EL students were missing at least one academic content area in any given semester.

These results add to previous research that EL students take fewer high-track credits, and take more low-track credits, as compared to students who are not EL. The placement of EL students who are already struggling academically into low-track classes can damage their sense of self and end up depressing their academic achievement rather than helping it (Umansky, 2016). The underrepresentation in advanced classes was even more apparent with EL students who have low academic achievement or low English proficiency. This evidence is not entirely unexpected, as EL students have lower average academic performance compared to non-ELs, but low-track classes can actually reduce the likelihood of graduation instead of increasing it. This research identifies a problem and proposes the question of how can schools provide English language support simultaneously with grade-level content? There are no state or federal guidelines as to how long academic delays are allowed, which can lead to the exclusionary tracking of students. It is more beneficial to EL students to teach content simultaneously rather than sequentially as to avoid low-level tracking (Umansky, 2016).

One way to prevent inequitable tracking in math classes is to provide linguistic modification on testing. As mentioned previously, there is a common misconception that math is a “universal language” (Li, 2016). In a 2010 study, Sato, Rabinowitz, Gallagher, and Huang set out to examine the effect of linguistic modification on the results of middle school math assessments for EL students. They compared the math performance on linguistically modified assessments across EL students, near English proficiency (NEP), and English proficient students (EP). In order to compare the results of these student subgroups, two different tests were created that measured number sense and operations as well as measurement. Efforts were taken in order to ensure that each test met stringent guidelines on content rigor and grade level standards (Sato et al., 2010). A large sample of 4,167 EL and non-ELL students were randomly assigned to take the original test or the linguistically modified test (Santo et al., 2010).

The results of the study indicated that EL students benefited the most from the modified assessment, but NEP students significantly increased their scores as well (Sato et al., 2010). EP students did not have a significant improvement when taking the modified test as compared to the original test. The linguistic modification was not found to alter any of the target math content assessed and was not found to be easier computationally (Sato et al., 2010). This result implies that many times EL students are inevitably tested when it comes to mathematics. The impacts of testing poorly due to the lack of English modification could be a major factor as to why many EL students are tracked in an exclusionary way. The difference in results for EL students when comparing the original test to the modified test was approximately the same impact as half a year of schooling (Sato et al., 2010). This could explain the disparity in advanced math classes between EL students and EP students. If EL students had access to modified math testing, they could be more accurately placed in accelerated or grade-level classes.

A study done by Maria Martiniello in 2008 provides further evidence that unmodified testing can lead to lower math placement for EL students. The main purpose of the study was to investigate the Massachusetts Comprehensive Assessment System (MCAS) math test and the impact of language complexity on item functioning for EL students compared to native English speakers (Martiniello, 2008). This study analyzed linguistic complexity from the 2003 MCAS math items and used think-aloud protocols in order to identify comprehension difficulties for EL students. Martiniello also compared items that posed difficulty to EL students and native English speaking students with similar math proficiency (Martiniello, 2008). The think-aloud interviews were administered to a sample of twenty-four fourth-grade EL students from a Massachusetts public school in the spring of 2005. The students interviewed represented a wide range of mathematics and English proficiency.

The results of the study helped to confirm previous research that indicated greater linguistic complexity increases the difficulty of math word problems for EL students as compared to native English speaking students (Martiniello, 2008). Martiniello further analyzed what words make the problems more difficult for EL students and found that vocabulary words presented a barrier to higher achievement, as well as words that may have multiple meanings based on context. There was also difficulty with words that are not academic in nature at all that most English speaking students would hear at home (e.g., *chores*). This can add another layer of difficulty to math word problems because the students have no context or ability to interpret the meaning from the question, because certain vocabulary was never explicitly taught to them. The results of this study imply that tests written for native English speakers do not accurately test the mathematical ability of EL students, which could lead to lower placement of EL students in math courses.

In a different study conducted by Fuchs et al. in 2008, researchers set out to examine patterns of difficulty between two domains of mathematics: computation and problem solving. The main purpose was to identify whether or not difficulty in one of the domains implied difficulty in the other. The data in the article was collected from 1,958 students in 89 third-grade classrooms in a southeastern metropolitan school district. 25% of students with scores one standard deviation below the mean on the Test of Computational Fluency, 50% of students with scores within one standard deviation of the mean, and 25% of students with scores one standard deviation above the mean. From among the 1,958 students, 924 of the students assessed were classified as having difficulty with computation, problem-solving, both domains, or neither.

The results of the testing revealed that difficulty in one of the domains does not necessarily imply that there would be difficulties in the other. Also, difficulty was distributed equally across the two domains nearly identically (Fuchs et al., 2008). This would indicate that having difficulty with problem-solving skills does not indicate that students have difficulty with computation or math in general. Results also show that language plays a critical role in the problem-solving domain, and inattentive behavior may inhibit computational skills (Fuchs et al., 2008). With respect to how this could impact EL students, it shows that language difficulties can lead to problem-solving issues, but it does not necessarily mean that students have computational difficulties. Students who have trouble with English can be misdiagnosed as having math difficulties when in reality, they just need some more support in English for the problem-solving aspect of mathematics.

The preceding studies identify the need for EL students to have some intervention or altered instruction. In 2021, Arizmendi conducted a study synthesis to determine how effective mathematics interventions for EL students were. More specifically, they investigated if interventions focused on math vocabulary yielded improvements on math measures and if the outcomes are different based on grade level or delivery method (Arizmendi, 2021). The number of EL participants included in the studies was 3,766, and articles needed to meet five requirements in order to be included in the synthesis. The intervention was implemented to improve math by focusing on math vocabulary, the participants were EL students, the study used single subject design, sufficient and interpretable data were reported, and each study reported treatment fidelity (Arizmendi, 2021). Each study included a control group and provided mean scores pre and post-test.

The results of the studies indicated that interventions yielded improved math results, and more specifically, individual interventions had better results than group interventions (Arizmendi, 2021). This indicates that EL students should be given access to individual or small group interventions when possible. The single subject studies that focused on math vocabulary and paraphrasing had the most significant positive changes (Arizmendi, 2021). The single subject interventions allow for more specific language focus, whereas a group setting is less effective in that context. In terms of age differences, interventions administered in kindergarten had greater effects than interventions administered in middle school (Arizmendi, 2021). This evidence implies that schools should have more resources for identifying language needs earlier so that students have more effective and long-lasting impacts. The human element has an impact as well, as traditional interventions had higher effect sizes when compared to computer-based interventions. These studies also indicated that a focus on numeracy skills was more impactful than focusing on mixed math skills, and longer lasting interventions over the course of the year yield higher results than half-year interventions (Arizmendi, 2021). The findings indicate that direct focus on children with math difficulties in one-to-one instruction should be prioritized over group interventions, with an emphasis on math vocabulary.

The positive impacts of interventions are not only felt by students, but a study done by Stuart et al. (2011) shows that teachers also benefit from interventions with EL students. This was a qualitative study conducted in an urban school of 334 students with diverse backgrounds and 26 teachers. The teachers responded to a survey after three years of implementing an intervention strategy called Response to Intervention (RTI). The researchers assisted in the implementation and collaborated with the school closely in order to give further support to teachers who did not have any familiarity with the system. After the data from the questionnaire was analyzed, teachers were asked to participate in interviews that dug deeper into their feelings toward the method as well as how it impacted the special education referral process for all students and in particular, EL students (Stuart et al., 2011).

The results of the study indicated that educators had increased collaboration, improved delivery of multi-tiered instruction, and fewer referrals to special education (Stuart et al., 2011). The participants also noted a change in the culture of the school, specifically regarding the staff's positive view of their own abilities. The interviews also revealed that the implementation of RTI led to general education teachers feeling more capable of working with EL students (Stuart et al., 2011). The results of this study show that an implementation of an intervention strategy can have a positive impact on the success of EL students but can also increase the self-image and efficacy of educators. Culture and morale are shown to be positively impacted by intervention strategies and an increase in collaboration.

Emphasis on Vocabulary and Leveraging Native Language

Something that schools may be hesitant about is leveraging native language, as they aim instead for immersion. Hwang, Mancilla-Martinez, McClain, Oh, and Flores (2020) set out to find the association between Spanish-English vocabulary knowledge and academic English proficiency. The subjects for the case were 62 elementary school students from three large urban school districts in the southeastern region of the United States. Each of the students were formally classified as an English learner by their school district. A questionnaire was given by translators in order to gather language use data. The families reported that, on average, they mostly spoke Spanish at home and lived around the poverty level. In order to test the students' knowledge, bilingual research assistants administered vocabulary tests in the fall of 2016, and the ACCESS test for EL students was conducted in April 2017.

The results indicated that expressive vocabulary was predictive of English learners' academic English proficiency. The same relationship was found between expressive vocabulary and English reading comprehension. What was interesting was that receptive vocabulary was not a predictor of English proficiency, highlighting the need to emphasize the use of vocabulary rather than simply understanding the word while listening or reading. This result is interesting because, with native English speakers, there hasn't been evidence to indicate a distinction between receptive and expressive vocabulary (Hwang et al., 2020). The study also found that leveraging a student's native language for English development led to improved results. Giving a native language translation may help the students have a point of reference when attempting word retrieval (Hwang et al., 2020). The implications of this study suggest that classrooms with EL students should provide ample opportunity for expressive vocabulary use, and possibly even more so than receptive vocabulary use.

A related study published by Brooks, Clenton, and Fraser in 2021 investigated the importance of vocabulary for EL learners' English comprehension. They set out to investigate factors that impact the comprehension of English learners, specifically comparing vocabulary knowledge to other skills like decoding, fluency, and general language ability (Brooks et al., 2021). The study included 31 learners from an international school in western Japan, and the students were a heterogeneous mix representative of the student body, which included first languages of Japanese, Korean, English, Dutch, and Croatian. Twenty-five of the students were identified as EL students, and the ages ranged from 11 to 15. The instruction at the school was delivered exclusively in English.

The results of the study indicate that there is a critical relationship between vocabulary knowledge and English comprehension (Brooks et al., 2021). Furthermore, vocabulary was found to have an independent effect on reading comprehension separate from the other factors of decoding, fluency, and language ability. When vocabulary was accounted for, the other assessments did not show strong correlations with reading comprehension (Brooks et al., 2021). Put simply, vocabulary was found to be the most important factor in reading comprehension so much so that other factors did not show a significant impact when the vocabulary data was normalized. The findings of this study add to a body of research that indicates vocabulary knowledge is fundamental for English comprehension. Another interesting point about this study is that it was conducted in a foreign country with a wide variety of different native languages, but the results still aligned with similar studies conducted in the United States. This indicates that the vocabulary emphasis is effective across all languages, rather than the dominant native language of Spanish of EL students in the United States.

Lesaux and Harris conducted a study in 2017 to investigate the reading performance of EL students as measured by word reading, vocabulary knowledge, and reading comprehension. This mixed method study analyzed test results and also included responses from students who described their understanding after completing the reading comprehension test. The participants of the study were 41 Latino students who were born in the United States. The students were all classified as EL and were children of Spanish-speaking immigrants. Students were enrolled in eight different public schools across an industrial city in the Northeast United States (Lesaux & Harris, 2017). The researchers administered a reading comprehension test, then conducted interviews following the test that gauged the perspectives of the students.

The quantitative results of the study concluded that many of the EL students who have difficulty reading in English have below-average vocabulary knowledge, but have adequate word-reading skills (Lesaux & Harris, 2017). Their vocabulary skills were measured in the 11th percentile nationally, but their word-reading skills were within the average range at 39th percentile and 53rd percentile, respectively (Lesaux & Harris, 2017). This led to results that indicated students had imprecise representations of the passage due to their struggle with vocabulary. In order to successfully make meaning from a text, students must have sufficient knowledge of the vocabulary involved. The qualitative element of the study indicates that students engaged in an active approach to reading, paraphrasing text, and making inferences. This evidence shows that EL students are not inactive readers that have poor comprehension strategies. In fact, this evidence shows that students may have the skills necessary to successfully make sense of academic content but lack the required vocabulary to arrive at an accurate conclusion.

The link between vocabulary and English proficiency extends further beyond English use in a language arts classroom, as Powell et al. found in a 2020 study that examined the link between math vocabulary and math performance. The purpose of their study was to measure the mathematics vocabulary of 3rd-grade students to determine if there was a correlation between students who have math difficulty (MD) and their vocabulary use. They investigated if mathematics vocabulary performance differences existed between EL and non-EL students with and without MD. The students in the study came from a large urban school district in the southwest region of the United States. The district reports that 55.5% of students are Hispanic, 29.6% are Caucasian, 7.1% as African American and 7.7% are in another racial or ethnic category. In the district, 27.1% of students qualified as EL students, and overall 52.4% of students qualified as economically disadvantaged (Powell et al., 2020).

An interesting result of the study showed that students without MD displayed low accuracy rates, below 50% accuracy for over half of the 45 items on the vocabulary test. This indicates that even students who do not struggle with computation find math vocabulary to be difficult. Accuracy rates for students who have MD with computation and word-problem solving had much lower accuracy rates than students without MD (Powell et al., 2020). This result highlights that students who struggle with math more so than average find mathematics vocabulary difficult, regardless of EL status. The correlation between mathematics vocabulary mastery and math performance indicates that math vocabulary should be more explicitly taught, even if students are not EL status. However, the impact of teaching vocabulary explicitly in math is greater for EL students. EL students may require additional support in order to effectively communicate using academic math vocabulary (Powell et al., 2020).

The importance of vocabulary proficiency in mathematics was further reinforced in a 2020 study conducted by Amanda Sanford et al. In this study, they implemented an instructional program with and without uniquely designed English language supports relative to their developmental needs. The study sought to discover whether adding the English language supports to mathematics vocabulary acquisition and word problem-solving containing the target vocabulary. The study was conducted with four Latino fourth-grade students in a rural elementary school in the Pacific Northwest. The school had an enrollment of 247 students, and 73.3% of the students qualified for free or reduced lunch. 51% of the students at the school were classified as EL students (Sanford et al., 2020). A baseline was established for all four students who were found to need both vocabulary support and general math support.

The results showed that students demonstrated an increase in their accuracy when defining vocabulary words during each phase of the intervention. At the beginning of the study, the range of the baseline for students was 0% to 30% accuracy, which increased post-test to 80% to 100% (Sanford et al., 2020). Alongside the increase in vocabulary accuracy came an increase in word problem-solving skills. The baseline range was 0% to 50%, which increased posttest to 80% to 100%. Before the study, these students were at risk of a learning disability diagnosis in mathematics, but after intervention they showed distinct improvement in math vocabulary acquisition and problem-solving. The focus and support of mathematics vocabulary not only increased the retention of mathematical definitions, but also increased the problem solving skills of the students who were involved. For a general education teacher, the implications of this study would indicate that there should be a heavier emphasis on mathematics vocabulary and that students receiving intervention should have specific English support when completing math interventions.

A study published in 2021 by Swanson, Arizmendi, and Li investigated the relationship between growth in math problem-solving and working memory. This quantitative study was conducted on 429 students in grades 1, 2, and 3 who are English language learners with the first language of Spanish. Students were administered a baseline test that measured math, reading, vocabulary, short-term memory, and working memory. The same test was administered a year later and again two years later to the same participants. The results and growth areas were compared and correlations were found between different aspects of the test and overall performance on higher-level math problems. The biggest aspect investigated was the connection between working memory and higher-level math problem-solving.

English learners with English as a second language have been found to perform lower than native English students on math measures because of the demands of processing multiple pieces of information simultaneously (Swanson et al., 2021). The researchers isolated growth in working memory as having a profound role in the mathematical problem-solving of EL students. They defined working memory as a limited-capacity system of temporary stores that include functions related to the preservation of information while simultaneously processing other information related to those functions (Swanson et al., 2021). EL students score lower than native English speakers on reading, science, and math because of the high demands of processing multiple pieces of information (Swanson et al., 2021). There is also difficulty in the fact that math vocabulary can have multiple meanings outside of a math context, which is especially difficult for EL students. The research indicates that by providing opportunities for EL students to practice their working memory, they will have increased performance on high-level math problems. An additional implication from the study is that performance on English measures of math problem-solving relies heavily on English vocabulary and calculation. This suggests that

EL students will draw from their second language knowledge, further strengthening the connection between English vocabulary acquisition and math performance.

An article published in 2008 by Joy Janzen reviewed research on teaching EL students in specific content areas. This study was a research synthesis that analyzed articles in peer-reviewed journals that were related to the field of EL students pertaining particularly to history, math, English, and science. For the purposes of this paper, I will only be discussing the results as related to the field of mathematics. The results suggest a strong connection between formal mathematical vocabulary and increased success in the field of math (Janzen, 2008). The vocabulary is wide-ranging and can be a barrier for EL students. Pedagogical issues are also discussed in the article.

Janzen found that the wide range of mathematical vocabulary is often not taught explicitly and has a negative effect on EL students. Formal mathematical language includes symbolic notation, visual displays, technical vocabulary, and distinct grammatical features (Janzen, 2008). By neglecting these language aspects within math, EL students are at a disadvantage when compared to native speakers. The article also highlights that much of the language used in mathematics overlaps with everyday language, but often does not carry the same meaning. This can lead to additional confusion for EL students who have to parse two different meanings of the same word while simultaneously processing a math problem (Janzen, 2008). Much of second language acquisition is made through conversational interactions, which builds a baseline of knowledge surrounding certain mathematical vocabulary that may not be correct (e.g. times, point, greater, factor, etc.). Without explicit instruction on formal math vocabulary, the students draw on prior knowledge that uses the vocabulary definitions with the wrong context. Lastly, there are additional words presented in formal algebra problems that confuse EL students. Many questions on algebra word problems contained confusing vocabulary that was not typically part of mathematical vernacular, for example, "extension" and "previous" (Janzen, 2008). Some general academic vocabulary should also be taught explicitly so that EL students have the same baseline knowledge as native English speakers when taking exams.

Vanessa Valley (2019) investigated the impact of teaching daily math word problems on math vocabulary use and word problem comprehension. This quantitative study compared numerical results from baseline and post-tests as well as a count of how frequently students used predetermined math vocabulary words. The study was conducted in an EL classroom at an elementary school in northern New England. The school has 300 students, and 25% of them are EL students. The classroom that conducted the study contained EL students in grades three through six. The languages spoken in the classroom were Arabic, Spanish, Turkish, and English.

The results of the study concluded that overall vocabulary mastery increased based on the post-test scores (Valley, 2019). The results also indicated that student mastery and oral use of vocabulary words increased significantly, as evidenced by an increase of 3.3 spoken key terms a day, with multiple students increasing their spoken vocabulary frequency by over twenty instances a day. The quantitative observations tied along with this result show that students were more capable of discussing key mathematical concepts when asking for assistance. Through daily practice of word problem comprehension, the student's oral communication was increased and their math comprehension was increased, however to a lesser extent. The summary of the study indicates that in future trials, the researcher would spend more time teaching vocabulary specifically in addition to word problems, further justifying the emphasis placed on math vocabulary.

Guglielmi (2012) examined relationships between native language proficiency, self-esteem, and math and science achievement. The goal was to find correlations that could help lead to policymaking that could help eliminate the achievement gap for EL students. A data sample taken from approximately 1,390 EL students composed of 750 Hispanic, 370 Asian/Pacific Islander, 190 Caucasian, 40 Black, and 40 Native American students were analyzed for this study.

The results of the Guglielmi study indicate that if outside factors were controlled, native language proficiency predicted not only English literacy success, but also self-esteem (Guglielmi, 2012). Through the increased success of English literacy, the proficiency in native language also played a significant role in the achievement of EL students in math and science. Overall, the study found that the more proficient students were in their native language, the more successful they were when learning academic language in English. What this means for EL learners of math is that retention and development of the native language alongside English academic language can increase achievement (Guglielmi, 2012). The fostering of native language growth not only helps academically but also maintains higher levels of self-esteem. It is important to teach academics to the student and promote a positive self-image so that students feel more empowered to tackle the difficult task of achieving English proficiency. Based on the results of this study, it is best to leverage and reference native language while teaching academic vocabulary and it has measurable effects in both math and science.

Building on the relationship between native language proficiency and mathematics, there was a study conducted by Swanson, Kong, and Petcu in 2018 that explored working memory in EL students who had serious math difficulties. The study set out to discover if students with math difficulties who become increasingly proficient in both languages have better math growth than students with less bilingual proficiency (Swanson et al., 2018). 157 EL students in grade 1 were selected from among four school districts in the southwestern United States. All children in the study were classified as EL students. All children in the study were Hispanic, were exposed to both English and Spanish, and received free or reduced lunch. This quantitative study was conducted by administering a number of tests in both English and Spanish that measured computation, reading, vocabulary, and working memory. Follow-up testing was done the next two years in grades 2 and 3.

The results of the study showed that working memory was directly related to growth in computational performance (Swanson et al., 2018). In addition, students more proficient in both languages showed more significant growth in working memory and, as a result, math calculation. This would indicate that by focusing on proficiency in both English and their native language, working memory and math skills increase as a result. While considering the results of this study as well as the results of a previously mentioned study that shows interventions are more effective at an earlier age, it would appear that early focus on vocabulary and language development has a greater impact on mathematics performance than focusing on computational skills. This also gives more credence to the idea that leveraging native language can be beneficial across all subject areas.

A study published by Orosco and Reed (2022) sought to investigate the correlation between EL professional development and performance for EL students. A multiple-baseline design was used to study nine third-grade EL students who have math difficulties (Orosco & Reed, 2022). The study also investigated to what extent professional development in word problem solving improved standardized math exam performance for EL students. The researchers wanted to see if the classroom success carried over and continued during standardized exams. A professional development program was designed for a special education teacher who delivered the instructional practices over a seven-week timeline in a pull-out math intervention program with third-grade ELs with math difficulties. In total, there were twenty sessions over ten weeks that went for twenty-five minutes each. The participating school had 559 enrolled students, of which 78% were hispanic, and 38.2% were EL students.

The students displayed low performance on baseline language-complex and computationally difficult word problems (Orosco & Reed, 2022). Throughout the implementation of the intervention strategies, the data showed that students were increasing their capabilities in word-problem solving as well as difficult math problems. As a result, the complexity of the problems was gradually increased in order to maintain further growth. After the intervention was complete, students maintained their problem-solving accuracy. In addition, results of a standardized test indicated a significantly improved ability of general problem-solving (Orosco & Reed, 2022). The evidence of the study suggests that professional development tailored specifically to the subject area and contextual needs of students can increase those students' achievement (Orosco & Reed, 2022). The results indicate that professional development is not only helpful for EL students in math, but also EL students who have math difficulties, further increasing the utility of professional development.

Scaffolding, Acceleration, and Metacognition

With the need for interventions established, as well as establishing the importance of vocabulary when it comes to mathematics, the next data presented will be concerning methods that suit best practice for EL math learners. Relevant studies indicate that scaffolding for EL learners, emphasizing metacognition, and accelerating instead of remediating has a positive impact. If students are taught remedial strategies, they won't have the opportunity to catch up to grade level in mathematics. Metacognition and scaffolding help students reach self-efficacy and independence in their math learning, unlocking potential and expediting growth.

Scaffolding

Scaffolding and being intentional for our EL students is something that requires lots of nuance and forethought. There can be a natural tension between helping students too much so that they become reliant and providing insufficient scaffolding that leaves students poorly equipped. A qualitative study conducted by Athanases and de Oliveira in 2014 sought to highlight that tension and discuss the implications for teaching EL students. This study investigated the nature of scaffolding that teachers practice at an urban high school with a high population of Latino students. The study focused on two classrooms that have 96% and 82% EL students, respectively. The school was selected based on the high number of EL students as well as the school's location in an urban setting. Observations were conducted for both of the classrooms through field notes, video recorded lessons, lesson plans, instructional materials, and interviews with staff, students, and parents (Athanases & de Oliveira, 2014). The classroom data were scored using the Classroom Assessment Scoring System and Standards Performance Continuum. One of the teachers observed was named Alexis, and the other teacher was named Consuelo. The two had different approaches and results but began with similar intentions.

In the case of Alexis, routine supports were consistently used to provide support for students in a variety of different ways, but it did not demonstrate scaffolding towards a gradual build of independence (Athanases & de Oliveira, 2014). Over supporting of EL students can restrict independent thought, and it can be difficult to find the balance between providing sufficient support and eliminating any challenge. The summary of the observations for Alexis' classroom indicated that she rarely adjusted or faded routine supports away depending on student performance (Athanases & de Oliveira, 2014). In other words, Alexis needed to identify which supports were redundant or remedial and adjust them or eliminate them altogether in order to continue pushing her EL students toward growth rather than dependence. The other teacher Consuelo was much more focused on fading those supports for her EL students. She even went as far as to regard unnecessary scaffolds as a 'crutch' that students may learn to rely too heavily on (Athanases & de Oliveira, 2014). Another difference that helped push Consuelo's class further was probing and pushing responses rather than accepting initial answers. Allowing students to reflect on their own responses and elaborate forces her students to think deeper about the content rather than providing a surface-level answer. The end goal of her scaffolding was to transfer responsibility over to the students as they were ready, fostering independence. In the end, scaffolding for EL students is full of tension for educators because of the risk of leaving students behind with insufficient scaffolding while simultaneously risking dependent learners by over-scaffolding. The results of this study indicate that consistently refining the scaffolds used based on the needs of students yields the most engaged and independent students.

Teachers play a critical role in the development of EL students' math performance, and balancing the rigor of curriculum with relationship building with students can be a difficult task. While addressing a rigorous curriculum is vital, there is another aspect that has been researched to be vital as well. In 2012, Lewis, Ream, Bocian, Cardullo, Hammond, and Fast researched EL student perceptions of teacher caring in relation to their self-efficacy and math performance. They sought to investigate the relationship between caring teachers, self-efficacy in math, and whether the relationships between the variables were dependent on English proficiency (Lewis et al., 2012). The study was conducted with Hispanic students in the fifth and sixth grades in

California elementary schools. The study used longitudinal data that was collected as part of a bigger research project that included over 3,000 elementary school students and more than 120 teachers from a Southern California school district (Lewis et al., 2012). The students participated in the Student Motivation Questionnaire which was given to all elementary school students in fourth through sixth grade in 2006 and 2007. The math scores were taken from a California Standards Test for math from the years 2006 and 2007.

The results of the study called attention to how social dynamics in the classroom impacts self-efficacy in mathematics. The feeling that a teacher cares about the student boosts their confidence in their ability to learn and leads to more tenacity and grit when working through difficult problems (Lewis et al., 2012). The second piece of information that they found was that self-efficacy boosts math performance. When investigating this link further, the researchers found that the magnitude of the relationship between caring and self-efficacy was more significant among Hispanic students who had yet to display English proficiency. Although the perception of teacher care had a positive impact on all students, the greatest impact was among Hispanic EL students who had the lowest average math performance. To find what specifically made the EL students feel more cared for, the researchers dug deeper into some indicators from the survey results. The researchers found that when teachers take a personal interest in the students as individuals, are empathetic towards the students' feelings, and listen intently to what the students have to say, the students feel more cared for and it builds their self-efficacy in mathematics (Lewis et al., 2012). The evidence indicates that the behaviors listed previously are more than emotionally relevant but are also educationally consequential (Lewis et al., 2012).

A study by Callahan, Humphries, and Buontempo (2021) investigated the connection between student-led discussion and math performance. More specifically, the researchers investigated the connection between EL students' participation in math discussions and their academic performance in math. The research team used nationally representative data from the Educational Longitudinal Study of approximately 15,000 high school sophomores across 750 schools. They supplemented student surveys with information from parents, teachers, and school administrators. High school transcripts were collected for most of the students, which provided detailed information on course history and academic achievement (Callahan et al., 2021).

The results of the study found that there is a positive relationship between participating in mathematical discussions and math performance. The study also found that EL students are more likely to participate in low-level classes as compared to grade-level or advanced classes (Callahan et al., 2021). This suggests that academic supports need to be included for EL students to access the same instructional opportunities as native speakers. This includes invitations to participate in discussion and modifying discussions so that EL students can more consistently participate. The disproportionate placement of EL students in low-level classes leads to the results of EL students participating in low-level math class discussions (Callahan et al., 2021). Furthermore, the study found that a positive correlation between math discussion and achievement extends to all students, not just EL students. For an effective student-led math discussion to occur, teachers must actively scaffold students' experiences and ask probing questions mindfully based on individual competencies (Callahan et al., 2021). The research indicates that EL students need to be provided equal opportunity for grade-level math courses, as well as scaffolded methods of mathematical discussion within the classroom (Callahan et al., 2021).

Metacognition and Math Success

In a study conducted in 2012 by Mehrak Rahimi and Maral Katal, metacognition is defined as "the ability to be aware of one's mental process" (Rahimi & Katal, 2012). Rahimi and Katal conducted a literature review in order to give a summary of metacognitive strategies as related to language learning. The study was a research synthesis that used data derived from a variety of students across different summarized studies. The synthesized studies were conducted in an ELL setting in Iran, with the intention of highlighting the importance of metacognition in language programs.

The results of the study indicated that metacognition could directly affect the learning outcomes of students (Rahimi & Katal, 2012). They also found that increasing metacognitive awareness increases the level of student performance, leading to higher-achieving students. Beyond the general purposes of metacognition, this study focused more intently on how metacognition can impact an individual's attempt to learn another language. Their research indicated that metacognition and language learning has a positive correlation with each other, and incorporating metacognition strategies makes learning more efficient (Rahimi & Katal, 2012). The reason for the positive correlation is that metacognitive strategies enable learners to play an active role in their own learning by allowing them to manage and select the methods that they should use for each task and eventually find the most effective method. This process lets the student take an active role as opposed to a passive role in what they are learning, and by doing so it helps reinforce new knowledge, leading to higher test performance, achievement, and learning outcomes (Rahimi & Katal, 2012). Beyond problem-solving skills, the research also indicated that successful language learners take conscious steps to understand what strategies they are using when reading, writing, and speaking. This information indicates that students who are more conscious of their thought processes are better at synthesizing and storing new information

(Rahimi & Katal, 2012). In addition, the research suggests that metacognitive language learning strategies are catalysts in achieving academic autonomy. This further allows students to individualize their learning, increase their levels of intrinsic motivation, and more effectively self-regulate (Rahimi & Katal, 2012).

Trigueros et al. (2019) found another positive consequence of metacognitive thinking. The researchers set out to analyze how students' emotional and motivational processes regarding the use of metacognitive strategies impact academic performance (Trigueros et al., 2019). This was a quantitative study that focused on English performance in Spanish students, as well as math performance in Spanish students. The study had 1151 participants aged between 13 and 19 years old and investigated the relationship between meeting psychological needs and academic performance. Specifically, the researchers sought to investigate whether academic motivation would positively predict metacognition strategies and performance, and that metacognitive strategies would positively influence academic performance (Trigueros et al., 2019).

The researchers discovered that positive emotions correlated with higher academic performance, metacognition strategy, and academic self-image (Trigueros et al., 2019). Teachers play a significant role in fostering the positive emotions of their students, allowing them to dig deeper into their own thinking processes. The perception that their teacher cared about them was the highest predictor of positive emotion in the classroom. When those needs are met, the students can prioritize their own learning, and the team discovered that academic motivation corresponded positively with the use of metacognitive strategy and that metacognition strategy corresponded positively with academic performance (Trigueros et al., 2019). The results suggest that teaching student autonomy is important in increasing both motivation and achievement. In teaching metacognitive strategy, students become more self-confident and independent, which in turn increases their achievement and mastery of English and Mathematics (Trigueros et al., 2019).

Although metacognition can be tied to overall academic performance, research also indicates that metacognition can specifically improve math skills. An analysis published in 2021 by Gemma Muncer et al. sought to investigate the relationship between metacognition and math performance in adolescents. The researchers conducted a literature review that contained the results of studies that consisted of 572,599 participants. All of the students were between 11-17 years old, and 50.3% were female (Muncer et al., 2021). Initially, the researchers sought an association between metacognition and math performance, but they also sought to investigate if the association between performance and metacognition was stronger for complex tasks as compared to simple tasks.

The research indicated that active use of metacognition during math problems is associated with increased performance (Muncer et al., 2021). In addition to the expected results, they also found that secondary-aged students benefited most from interventions that promoted metacognition strategies. In addition, the results indicated that when attempting a more complicated mathematical task, metacognitive strategy implementation predicted a higher outcome (Muncer et al., 2021). The relationship indicated that when students are approaching critical exams that may help progress or hinder their academic career, individuals who showed metacognitive skills performed better in math tasks (Muncer et al., 2021). This indicates that not only for deep comprehension is metacognition important, but it also could have potential career implications based on the performance of students on important exams like the ACT or SAT. The more complex a math task is, the more useful and impactful the use of metacognition becomes.

In a similarly inspired study conducted in 2011 by Gokhan Ozsoy, students were placed in a control group and a study group in order to investigate the effects of metacognitive strategy instruction on mathematical problem-solving achievement (Ozsoy, 2011). This quantitative study consisted of 47 fifth-grade students in a primary school in Ankara, Turkey. Twenty-four of the students were placed in the experimental group, and 23 were placed in the control group. Both groups were pre-tested, and the post-test results were compared in order to study the differences between the two forms of instruction (Ozsoy, 2011). The results of the study showed that the instruction of metacognitive strategy in the experimental group led to a statistically significant increase in mathematical problem-solving, and 42% of the total variance in math achievement could be explained by metacognition (Ozsoy, 2011). However, in the control group there was not a significant increase in achievement. This study gives validity to the correlation between mathematical problem-solving skills and teaching metacognitive strategies.

In addition to having an impact on math achievement, metacognition has been found to increase achievement in a second language achievement as well. Raoofi et al. (2014) indicate that metacognition is a significant contributor to success in a second language. This publication was a synthesis of many studies that had multiple guiding questions pertaining to metacognition and the development of a second language. In total, the researchers examined the role of metacognition in learning seven languages as a second language. The conclusions reached by the researchers indicate that it is possible to impact a student's language performance through metacognitive-focused interventions (Raoofi et al., 2014). The research also suggests metacognition is a predator of language performance and second language acquisition. It also indicated that mastery of the primary language has an impact on second language metacognition (Raoofi et al., 2014). The conclusion of the synthesis suggests that educators should focus both on the language content and on the processes of learning, leading to more autonomous and self-regulated language learners.

Implementation

Scaffolding, classroom social dynamics, and metacognition all play an important role in the math learning of EL students, but some educators may still not know what tangible strategies to use in their classrooms in order to implement those ideas. One study (Fadillah & Nurhasanah, 2021) was conducted to investigate the connection between self-efficacy and metacognition. This qualitative study used self-efficacy questionnaires in order to identify any connections between self-efficacy and metacognition. Self-efficacy was defined in this study as the "belief that learning performance will affect the student's cognitive, motivation, and affective processes" (Fadillah & Nurhasanah, 2021, p. 2). The results showed that subjects who had high self-efficacy when solving a complex math problem were able to meet all of the study's defined indicators of metacognition (Fadillah & Nurhasanah, 2021). The results of this study suggest that students who have been given reinforcement to believe that their individual efforts will yield results tend to be more successful in the process of metacognition. Building a student's academic self-perception can have drastic results on the mastery of mathematics. These results suggest that educators should focus beyond skill acquisition and practice and also focus on building a student's sense of self-efficacy in order to achieve desired outcomes.

The research so far has shown that building self-efficacy and metacognition can be extremely helpful in both language acquisition as well as math skills. However, this can be difficult to achieve in a traditional classroom setting when a student finds themselves already behind in those skills when learning a second language. A study conducted in 2013 sought to assess the effectiveness of a pullout intervention program when seeking to improve math capabilities in second-grade ELL students. This quantitative study was conducted on six second-grade Latino ELL students who were considered to be at risk for math disability in a school district in southern California. The students went through 17 intervention sessions that averaged around 23 minutes per session over a five-week period (Orosco, 2013). The results indicated that students increased their ability to solve word problems, and the students were able to maintain the knowledge during follow-up sessions (Orosco, 2013). The interventions were scaffolded, showing that the ELL students needed help with understanding the math vocabulary, and did not in fact struggle with number sense or calculation skills. The intervention strategy also incorporated native language that allowed them to better understand the prompts, granting access to the math curriculum that had previously been inaccessible due to language barriers. As previously mentioned in this paper, the language support was reduced gradually as the students gained more mastery over their second language. This study indicates that native language intervention that has an emphasis on comprehension strategy can help students' math performance (Orosco, 2013).

A similar study was published in 2019 that investigated the impacts of paraphrasing interventions on word problem-solving accuracy for ELL students who struggle with math (Swanson et al., 2019). This quantitative study was conducted with 142 third-grade students, some of whom were monolingual, while the others were ELL students. There was a control group and an experimental group, which received paraphrasing interventions in order to help word-problem solving skills. The results of the study indicated that both ELL students and monolingual students benefited greatly from paraphrasing interventions. The problem-solving accuracy increased the most for ELL students without math difficulties and also for monolingual students. The increase in comprehension was substantially smaller for ELL students with math difficulties (Swanson et al., 2019). This suggests that ELL students who do not struggle with number sense or calculation benefit the most from paraphrasing word problems. This evidence gives further credence to the idea that ELL students need English language support in order to achieve their highest level of mathematical success. ELL students with math difficulties would need more support with computational skills before they work on paraphrasing skills.

The previously mentioned strategies rely heavily on the ability to perform interventions in individual settings or in small groups. However, this is not always possible, depending on staffing issues or scheduling within a school building. A study published in 2013 sought to investigate the impact of ELL student participation in large-group discussions on their math comprehension (Turner et al., 2013). This qualitative study focused on how educators can use different methods in order to provide opportunities for ELL students to participate in a mathematical discussion. The enactment of these strategies led to a restructuring of participation in general for the students and teachers (Turner et al., 2013). When teachers used explicit statements that validated ELL students' reasoning, invited them to share or justify their thinking, and invited peers to respond to an ELL's idea, those students saw themselves as more competent and confident mathematicians (Turner et al., 2013). By specifically inviting students to share their thoughts, then immediately validating their thinking, the students grew in confidence and self-identity. The students were also given a chance to rephrase or find specific words as needed in their native language. This also leads to more self-validation and self-expression, as students feel more confident in their additions to classroom discussion (Turner et al., 2013). As previously mentioned in this paper, self-efficacy plays an important role in mathematics achievement. By using strategies that provide explicit opportunities for ELL students to safely participate in the discussion, educators can build self-efficacy and metacognition, in turn increasing math performance.

CHAPTER III: DISCUSSION AND CONCLUSION

Summary

EL students are more likely to be placed at below grade level in math than students who speak English as a first language (Martiniello, 2008; Thompson, 2017; Umansky, 2016). The language barrier prevents students from achieving their highest potential, and intentional support is needed for EL students who are learning math. EL students benefit from interventions and linguistically modified assessments in math, increasing math achievement (Arizmendi, 2021; Fuchs et al., 2008; Sato et al., 2010). Researchers found that students who struggle with problem-solving skills do not necessarily have difficulty with computational skills and that those students simply needed more language support in order to fully comprehend complex mathematical prompts (Fuchs et al., 2008; Sato et al., 2010). Research also suggests that additional training and intervention resources for instructors have a positive impact on EL students, as well as a positive emotional impact on teachers (Orosco & Reed, 2022; Stuart & Rinaldi, 2011).

The connection between language acquisition and math performance is further connected by studies that show increased literacy in an EL student's native language predicts literacy in their second language, as well as problem-solving skills (Guglielmi, 2012; Hwang et al., 2020, Swanson et al., 2018). If students are allowed to use their native language as a support, they build literacy in both their native language as well as their second language. Teachers can help students develop more mastery of their second language by leveraging the knowledge and literacy that those students have in their first language. When looking at specifically what aspects of language had the highest impact on math mastery, researchers found that vocabulary acquisition had the strongest correlation to math and problem-solving comprehension (Brooks et al., 2021; Hwang et al., 2020; Janzen, 2008; Powell et al., 2020; Sanford et al., 2020). The aspect of language that benefited students the most was vocabulary, in both language proficiency as well as math proficiency. Daily practice of word problem-solving, and teaching skills necessary to process all relevant information simultaneously also led to an increase in math performance (Lesaux & Harris, 2017; Swanson et al., 2021; Valley, 2019). The research indicates that when teaching math to EL students, educators should emphasize language literacy, and more specifically, vocabulary acquisition and mastery.

Developing student agency and building metacognitive skills helps increase student achievement in math (Muncer et al., 2021; Ozsoy, 2011; Trigueros et al., 2019). In addition to math achievement, metacognition and student agency/independence are connected to an increase in language mastery (Rahimi & Katal, 2012; Raoofi et al., 2014; Trigueros et al., 2019). This research shows that if a student is actively thinking about the processes they are using while reading or solving problems, then they will achieve higher results. This process can be difficult for EL students who need to think in a foreign language, so scaffolds and supports are needed in order to build toward independent thinking. However, the supports in place for EL students should be gradually released over time as those students improve, allowing the opportunity for EL students to attain full agency in their own learning (Athanases & de Oliveira, 2014; Orosco, 2013). EL students benefit from language supports that focus on vocabulary and prompt comprehension, vastly improving their accuracy in more complex math problems (Orosco, 2013; Swanson & Kong, 2019). These strategies help EL students build more self-efficacy and agency over their own learning. Metacognition has been linked to higher achievement in both language and math, and high self-efficacy has also been linked to high levels of metacognition (Fadillah et al., 2021). Building self-efficacy is something that educators can implement by facilitating EL student participation in math discussions with a positive social dynamic, boosting self-confidence and math language mastery (Callahan et al., 2021; Lewis et al., 2012; Turner et al., 2013). By providing a space for EL students to participate in mathematical discussions, they get an opportunity to use newly acquired language and vocabulary. The students also get a chance to validate their reasoning, providing practice opportunities for metacognitive skills and self-efficacy.

Limitations of the Research

Initially I limited my research to studies that focused specifically on EL mathematics and the best practices for teachers to implement. As I dug deeper into what those practices were, I broadened the research to include metacognition as I encountered more results that correlated math and language performance to metacognition and self-efficacy. I excluded metacognitive research that wasn't directly related to language or math proficiency. I also excluded research that compared the effectiveness of metacognition between different subject areas, so I could focus specifically on language acquisition and math performance.

One thing I wish I had found more research on was on secondary EL students. A lot of the research I found was conducted on elementary school or middle school-aged students. Another topic that I did not find research on was how different levels of EL students respond to different interventions based on their needs. Most of the research that I found seemed to imply at least some level of understanding in their second language, but EL students in Minnesota are placed on a scale from level one to level five based on their English mastery. I was hoping to encounter some research that showed some strategies for those progressions. Lastly I didn't find research on best practices for EL students with math difficulties. Much of the research found that the vocabulary and language supports helped all students but not as effectively for EL students who had math difficulties. There weren't many studies on how to help computational skills for EL students.

Implications for Further Research

Something that would help educators is research on what strategies and methods work best for varying levels of EL students based on both language mastery and math mastery. In practice, a classroom full of EL students will have a varying range of skills and needs, so finding what is most effective for all of those specific needs would be helpful. It would also be helpful to measure at which pace supports should be taken away in order to build more independence. Another idea that would be interesting to research is the impact of focusing entirely on literacy and language acquisition for new EL students before sending them to other subjects as literacy is tied to performance in math. For example, would it be more beneficial for a new coming EL student who has no second language mastery to spend an entire first year focusing entirely on vocabulary and literacy as opposed to spreading out over different subjects (Math, Language Arts, Social Studies, Science, electives, etc.). It would be interesting to see if those students catch up in math mastery after having an extended period of time devoted solely to language and vocabulary acquisition, especially considering the existing research that ties literacy to math achievement.

Personal Application

I chose this topic specifically because I am a math teacher who has four classes that are exclusively EL students. My goal was to better understand how I can provide the best learning opportunities for those students. Because of the nature of EL students arriving throughout the year, and the variety of mastery levels in English and math, I wanted to get to the core of what can help them achieve a higher level of math proficiency. When I took on the role of our school's

EL math teacher, much of the material was remedial and not up to grade level. I knew that this was not equitable for those students, and did not prepare them adequately for a non-sheltered environment of learning. I've been teaching those classes for two years and have tried to implement improvements over that time, but did not have the most support or knowledge in order to do so effectively. This was the inspiration for my research topic, and I am happy to have learned so much about how I can immediately help my students.

One direct application that I will immediately implement is spending more time emphasizing vocabulary. In the past couple years, I taught vocabulary directly before every lesson started, but I did not give the students enough practice opportunities to reinforce the new words that they were learning. I want to include tasks where the students write and speak their new vocabulary in their own words, allowing them to have some more agency over the new words they are learning rather than trying to memorize definitions. The evidence suggests that a strong foundation of vocabulary comprehension is vital to a deep understanding of mathematics, so I need to reassess the balance of computational practice and vocabulary development. Sometimes it can be easy to lose sight of the long-term goals when you are teaching day-to-day in the classroom. I might have leaned too heavily into students being able to meet the standards of the moment, overlooking the task of deepening mathematical understanding and thinking beyond what the current standard is. I hope that by emphasizing vocabulary much more in the future, I can strengthen my EL students' deeper understanding of math, rather than helping them memorize processes for the next exam.

Based on the research, tasking students with explanations of their thinking and describing their process is a catalyst for metacognition and more agency in learning. Reflecting on the past two years, I have been too satisfied with my EL students simply showing their work, instead of digging deeper and asking them to explain their thinking using words. This doubles down on the vocabulary practice, and also challenges the students to form deeper connections instead of regurgitating information. I plan to invite students to explain their problem-solving process out loud, and ask students why they used each mathematical process that they did. This will help deepen understanding for students when they have the correct processes, and will also help students to identify different aspects for improvement. Both of these skills require self-reflection and metacognition, which in turn increases student agency. Along the same lines of thinking, I also want the students to explain their thinking to each other, leveraging their shared native language. The research indicates that students who have more literacy in their native language are more likely to be successful in both their second language comprehension and math achievement. By allowing students to translate and use both English and their native language, I hope to strengthen the connections between vocabulary in their native and second language, allowing for deeper, more reinforced comprehension.

Another helpful strategy that I can try to use is small-group interventions. This is definitely challenging with large class sizes, and I will advocate for smaller classes as much as possible in the future. With my co-teachers help, we can identify and organize smaller groups of students who may need targeted support and help them more directly while the other teacher is working with the rest of the class. I think the evidence shows that interventions help accelerate students who may be struggling, even though they may be taken out of the large classroom setting for small periods of time, causing them to miss some instruction. This does require resources to be invested in EL, and considering the current trends of budget cuts and low pay for teachers, I think a very real-life application of this research would be lobbying and advocating for more resources for our students. Lack of resources signifies cuts in staffing, which oftentimes leads to larger classrooms and fewer capabilities for targeted interventions. On a personal level, I am able to use the resource of my co-teacher to help fulfill this goal. However, education as an entity is facing troubling times and I believe that the best course of action is fighting and advocating for the resources we need in order to equitably educate our children.

Conclusion

EL students face challenges that spread across all subject areas in school. Learning a specific subject at a high level while being instructed entirely in a second language understandably leaves EL students at a disadvantage. Educators must ensure that EL students have equal access and opportunity to grade-level and advanced curricula. Research shows that emphasizing vocabulary, and promoting the use of native language as support, increases second-language and mathematics achievement. It is also important to provide opportunities for EL students to practice their new vocabulary in a challenging environment that allows for deeper thinking. By asking students to explain their mathematical reasoning, they get a chance to implement new words while also reflecting on their own processes. This helps students practice metacognition, which is shown to increase student agency as well as achievement across subject areas. EL students benefit from focused interventions that supplement their classroom learning. The lack of resources devoted to our children's learning is causing a funding stranglehold that cuts academic resources, keeps pay for educators low, and is understandably driving away staff from holding underappreciated, underpaid jobs. Although these strategies I've reviewed are extremely helpful, they cannot be practically implemented without enough support. My hope is that our society realizes the importance of investing in our future, and we can get the financial support that we need in order to give EL students, as well as all other students, the education that they deserve.

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