Supporting the Use of Mathematical Language in Discourse and Student Self-Efficacy in Mathematics

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Abstract

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Chapter 1: Introduction and Literature Review

Introduction and Rationale

There is an enormous amount of research on how people learn. Most researchers agree that knowledge builds on existing knowledge or schema and that language and communication are essential to learning. Therefore, understanding and fluency in the language of instruction is imperative to academic success (Zimmerman, Bandura, & Martinez-Pons, 1992).

There is a great deal of recent research on how to best teach the growing number of English Language Learners (ELL) the academic register[1] they need to be successful in school, while simultaneously attending to the content to be learned. ELL's do not simply need to learn a new language; they must learn the more formal register of the language in order to succeed in school. In order to create equity in our society, traditionally marginalized populations must have access to the language spoken by those in power (Gutierrez, 2002; Johnson, 2006). In schools, the language of power is academic, or school language.

It is not only ELLs who struggle with academic language. There is a large population of English speaking students from low-income families who also struggle with the academic language required for school success. Many studies have examined the life long impact of poverty on language proficiency (Gutierrez, 2002; Hart & Risley, 1995; Boaler & Staples, 2008;). Families from low socioeconomic status (SES) backgrounds or generational poverty, typically use a

[1] Register is the variety of language, formality, choice of vocabulary, pronunciation, and/or syntax, usually determined by the communicative purpose, social context, or social status of the user (New Oxford American Dictionary)

different linguistic register than those from higher SES families (Hart & Risley, 1995). Research has shown that the academic register is not often spoken in the homes of very low-income families. Low SES students, who have learned a different register of English at home, must become proficient in a new register (academic) in order to be successful in the current school system (Krashen & Brown, 2007).

During a student's academic career, success in content areas depends upon the student's proficiency in language and vocabulary. When the written and spoken language is mastered, the other subjects and content areas become more accessible. Mathematics is not that simple. It uses a language of it's own that is filled with symbols and vocabulary not easily transferred from other content areas. For those who are already at a linguistic disadvantage in our culture, such as ELLs or students from poverty, learning the mathematical register may be as confusing and intimidating as trying to learn a new language (Matthews, 2008).

I am a teacher in a diverse and poverty-impacted school district and my classroom reflects the diversity of the district. With few exceptions, the students from low SES homes have needed the most support in reading and math. I have spent a great deal of time successfully supporting students as they learn and practice language and vocabulary in reading and science. Recently, when one of my students asked me what I meant when I asked for the *sum* of two numbers[2], I realized how important language is to mathematics learning as well as other content areas.

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[2] I was not certain if the student confused 'sum' with 'some' or if the meaning of 'sum' was not known. This brought the importance of academic language in learning mathematics to my attention.

Much of the research I have read during my graduate coursework has centered on equity and mathematical discourse. Intentionally focusing my teaching on the specialized language essential to mathematics will help my students become more confident and capable learners, allowing them to have greater access to the mathematics. My goal is to support student understanding of the academic language needed to participate effectively in a math learning community and to thereby create an equitable learning environment.

In this chapter, I discuss current research in learning theory, as well as establish background for the focus of my research. I describe the connection between low SES students, language proficiency, and academic achievement. The majority of the research I examined promotes the idea of mathematics language as a form of academic register and that understanding and communicating in that register helps students build their belief about their ability to be successful in mathematics, or self-efficacy. I wondered if helping students understand mathematical language would build self-efficacy in mathematics, and in turn, engage students, allowing them to be successful mathematicians. My interest in this relationship led me to focus on the following question:

How will supporting students' use of mathematical language during classroom discourse influence their feelings of self-efficacy in mathematics?

Research on Language and Mathematics

Academic language. Learning occurs in a predictable manner. As a person observes and interacts with the world, the environment provides stimulus

that the person's brain processes in order to understand it and neural networks are built (Zull, 2002). Piaget called those existing neural networks "schema", which is the knowledge a person uses as a foundation for new learning. Piaget believed that new learning builds upon this existing schema. New learning requires words in order to allow the brain to sort and classify experiences into the learners' neural network for later access. All new experiences are "recognized, added, and assimilated to past experiences or let go unnoticed or unnamed because there are no words and no past experiences with which to link them" (Hart & Risley, 1995).

Social cognitive theorists such as Chomskey, Bandura, and Vygotsky all explored language, the idea that communication with others is essential to learning, and how most communication between people is usually through language. Academic language, a formal register of spoken language, is commonly spoken in educational settings (Krashen & Brown, 2007). Academic language has been called "the language of power" (Khisty & Chval, 2002; Scarcella & Pompa, 2011) because it is the language common to white, middle to upper class society. Proficiency in academic language[3] is essential to success in school (Lott-Adams, Thangata, & King, 2005) because it is the language commonly used in classrooms and textbooks.

Not all students have equal access to academic register. Traditionally marginalized populations, such as ELLs and families of generational poverty do not have the same access to academic language as middle and upper SES populations. Many of the current studies focused on the relationship between ELLs and academic language; however, there is a relationship between students

[3] Academic language is the language commonly used in classrooms and textbooks.

of poverty and language proficiency that must be addressed in order to provide equity for these students.

According to Hart and Risley (1995), there is a direct relationship between a family's socioeconomic status and the variety, complexity, and amount of language children are exposed to in the household. They found an enormous difference between the numbers of utterances children from low and higher SES households hear in early years. Children from higher SES families experienced between three and eight million more words in a year than children from low SES families. Dudley and Lucas (2009) found a strong relationship between the early language proficiency of children and later academic success. Consequently, teaching academic language is important to student learning.

Understanding the language of instruction is imperative to academic success. The difference in language proficiency between low and middle to high socioeconomic status has an enormous impact on academic achievement. Research showed that students from low-income families do not have the same access to academic language as those from higher income families (Reyes & Stanic, 1988). Addressing the needs of traditionally marginalized populations in the classroom allows them to succeed in school and creates a society in which all people have access to the same opportunities.

Mathematical language. Early exposure to academic language has a profound impact on later learning (Dudley & Lucas, 2009). Early exposure to the words used in mathematics may also have an effect on later mathematical

understanding. In one study, Rudd, Lambert, Satterwhite and Zaier (2008) examined the way in which teachers talk about math with very young students. They found that over 70% of the mathematical language used with young children was either number or spatial, or words involving labeling numbers or location. The mathematical language was kept simple and used lower level thinking skills. Few of the teachers used any complex language, such as that used for operations, patterns, or data (Whitin & Whitin, 2003). Considering current research, which clearly shows the necessity of language exposure in order to build schema, one may wonder whether this oversimplified vocabulary in mathematics has an impact on later mathematical learning.

The language used in mathematics classrooms is more complex than the everyday language to which students are accustomed. Some researchers have even claimed that mathematics is a language unto itself (Bullock, 1994; Khisty & Chval, 2002; Matthews, 2008; Zevenbergen, 2000). Furthermore, mathematics uses vocabulary that overlaps everyday English, but may have a different meaning than in conversational English (Gough, 2007; Hersh, 1997; Raiker, 2002; Rubenstein & Thompson, 2002; Rubenstein, 2007; Seidel & McNamee, 2005). There are mathematical words that are rarely, if ever, spoken outside the mathematics classroom (Raiker, 2002; Rubenstein, 2007). Even native language speakers must learn the special language of mathematics in order to succeed. Students who speak a first language other than English or use an informal/working class register have a huge gap to overcome in order to be successful in the language of mathematics (Zevenbergen, 2000). Teachers must

be aware of the language they are using in the classroom, explicitly teach students vocabulary needed for understanding, and ensure that all students understand any specialized words used in the lesson. Table 1.1, 'Categories of Mathematics vocabulary' illustrates some of the specialized mathematical language that may cause confusion for students.

Rubenstein (2007) identified some common mathematical language with which students (and teachers) sometimes struggle. She encouraged focusing on these words with students and reminded teachers that in mathematics, every word matters. She concluded her article by stating, "Language is a major medium of teaching and learning mathematics; we serve students well when we support them in learning mathematical language with meaning and fluency" (p. 206).

Research has demonstrated the importance of teachers using mathematical language when talking to students (Khisty & Chval, 2002). They found that simply teaching the vocabulary to students does not necessarily support their thinking. Teachers must move beyond 'word walls' by using the academic language in context of the mathematics to be learned (DfEE, 1999). This plays an important role in student understanding. When classroom discussions focused on precise mathematical language becomes the classroom norm, students become more comfortable using that language to express ideas and defend justifications.

It is important for teachers to recognize the importance of language as a tool for teaching mathematics. Bradley's study (1988) clearly showed a connection between mathematical language proficiency and conceptual and procedural proficiency. Bradley suggested providing mathematics language

activities during instruction might help students bridge the gap between procedural knowledge and conceptual understanding. Bradley reminded educators that vocabulary instruction is taught to strengthen reading comprehension. Vocabulary, concepts, and procedures are needed to strengthen mathematics comprehension. Kazemi and Stipek (2001) expressed the importance of language proficiency in mathematical discourse. Their findings demonstrated that students must be able to communicate their understanding to the teacher and classmates as well as be able to understand the thinking of others. Mathematical language proficiency allows teachers and students to engage in discourse and share meaning and understanding with others.

In the past, traditional methods in mathematics classroom have been procedure centered; students followed procedures and recited mathematical rules and facts (Whitin & Whitin, 2003). If students could follow procedures, learning was considered to have occurred. We now know much more about what it means to learn mathematics and how conceptual understanding (NRC, 2001) and high cognitive demand (Henningsen & Stein, 1997) plays an important role in the learning of mathematics. When students are not proficient in mathematical language it is difficult for them to participate in high-level math discourse.

Table 1.1 Categories of Mathematics Vocabulary Challenges with Examples

Table 1
Categories of Mathematics Vocabulary Challenges, with Examples

Category of Challenge	Samples in Number Strand	Samples in Geometry and Measurement Strands	Samples in Algebra Strand	Samples in Data Analysis and Probability Strand
Some words are shared with everyday English, sometimes with distinct meanings, sometimes with more technical meanings in mathematics.	Fraction Product Power Prime	Similar Reflection Acute	Variable Function Origin Relation	Mode Average Median
Some words are shared with science or other disciplines.	Divide (continental) Degree	Prism Altitude Vertex	Power Degree Vertex	Experiment
Some words are found only in mathematics.	Denominator Percent	Isosceles Hypotenuse	Integer Polynomial	Outlier Histogram
Some words have multiple meanings in mathematics.	Round	Round Square Cube Tangent	Square Cube Range Tangent	Range
Some words are learned in pairs that often confuse students.	Factor and multiple At most and at least	Radius and diameter Complement and supplement Area and perimeter	Domain and range Horizontal and vertical Associative and commutative Solve and simplify	Dependent and independent Combination and permutation Horizontal and vertical
Some words sound like others (homonyms and near homonyms).	Sum, some Two, to, too Hundreds, hundredths	Pi, pie Plane, plain Complement, compliment Theorem, theory	Intercept, intersect	Leaf, leave
Modifiers change meanings of words in critical ways.	Fraction versus improper fraction Denominator versus common denominator Factorization versus the prime factorization	Bisector versus perpendicular bisector Polygon versus regular polygon Trapezoid versus isosceles trapezoid	Linear equation versus linear equation in slope-intercept form	Number versus random number Deviation versus standard deviation Score versus standard score

(Rubenstein & Thompson, 2002)

Mathematical discourse. Discourse in mathematics is a popular subject in current educational research. Although the focus of this study investigates the relationship between academic language and self-efficacy in a math classroom and does not explicitly address discourse, it is vital to understand discourse as an underlying process for the development of academic language.

Classroom discourse is an effective way for teachers to assess student understanding (Walshaw & Anthony, 2008). However, students must have access to mathematical language in order to utilize discourse as a tool to reveal their mathematical thinking. In order to support the development of mathematical language, teachers can listen to student explanations and question them further to assess the student's mathematical understanding. Teachers can assess the depth of a student's understanding by listening to discussions and by asking them to explain further.

Principles and Standards for School Mathematics (NCTM, 2000) challenges teachers to encourage students to think, question, solve problems, and discuss their ideas, strategies, and solutions (p 18). Herbel-Eisenmann and Breyfogle (2005) found that some questions promote deeper mathematical thinking than others do. They showed that high-press questions, or questions that push students to extend their thinking, helped students articulate understanding so that their ideas and justifications made sense to the teacher and the other students in the class.

Understanding mathematical language can increase students' confidence and participation in the mathematics classroom (Pierce & Fontaine, 2009;

Topping, Campbell, Douglas, & Smith, 2003; Bradley, 1988). When students gain confidence and participate more, they require less teacher guidance. Research shows that when students self-regulate, or work independently, they are more successful in academics and feel more confident and self-assured (Zimmerman, Bandura, & Martinez-Pons, 1992; Ozgen & Bindak, 2011). Students who are able to communicate their understanding gain status because their ideas are more valued and respected (Cohen, 1994). With this gain in status, students find intrinsic motivation to succeed in mathematics. Intrinsic motivation allows students to gain self-efficacy, enjoy mathematics more and be more successful in mathematics (Meuller, Yankelewitz & Maher, 2011).

Self-efficacy, achievement, and growth. Self-efficacy is a term popularized by Albert Bandura, a psychologist who researches social cognitive theory. Bandura describes self-efficacy as the belief one has in his or her capability to perform specific tasks in any particular situation (1977). Individuals with a strong sense of self-efficacy will view difficult challenges as if they were a puzzle, are more likely to stick with the problem, and recover quickly when something does not succeed. Those with a weak sense of self-efficacy will avoid difficult tasks altogether, focus on personal failings, and give up quickly when the tasks are difficult. Building a strong sense of self-efficacy will help students develop confidence, allow students to stick with difficult problems, and increase mathematical proficiency (Zimmerman, Bandura, & Martinez-Pons, 1992).

Increased self-efficacy can increase mathematic achievement (Ben-Yeheda, Lavy, Linchevski & Sfard, 2005; Metallidou & Vlachou, 2007; Zimmerman, et al. 1992). Zimmerman, Bandura and Martinez-Pons (1992) explained that personal goals play a key role in students' attainment of grades in school. They found that the higher the student's perceived self-efficacy, the higher the goals students set for themselves. The students' feelings of self-efficacy influenced setting academic goals for themselves, and their achievement of these goals. The parents' goals were significantly higher than those their children set for themselves. Zimmerman et. al. (1992) found that students did not have high aspirations simply because others wished it. Academic experiences need to be structured in a way that enhances students' sense of academic efficacy and encourages intrinsic motivation to succeed.

Getting students to articulate their thinking and engage in mathematical discourse is often a difficult task for teachers yet the research clearly demonstrated the importance of students' development of academic language as a way to become proficient in high-level mathematical discourse. Educational research has identified several strategies teachers can use that support the practice of teaching students the academic language of math, as well as use that language to justify and defend their ideas. Focusing on how students use the language of mathematics in their classroom discourse may increase student understanding and in turn, self-efficacy.

Practices that Support Mathematical Language Development

Sociomathematical norms. One way to promote the use of mathematical language in discourse in a classroom is for the teacher to establish sociomathematical norms. Yackel and Cobb (1996) explain that social norms are those that sustain classroom micro-cultures. These are the expectations that a teacher has in any classroom or subject area, such as how to head a paper, or when one may sharpen pencils. Sociomathematical norms are the norms and expectations present specifically in a mathematics classroom, such as what counts as justifying work, finding a different way to solve a problem, or expecting all members of a group to be able to explain the others' thinking. Yackel and Cobb found that one set of sociomathematical norms did not fit all classrooms and that the expectations were continually renewed and modified to fit the needs of the class. Yackel and Cobb also noted that "in the process of negotiating sociomathematical norms, students in these classrooms actively constructed personal beliefs and values that enabled them to be increasingly autonomous in mathematics" (p. 474). As previously discussed, autonomy and self-regulation are extremely important to a students feeling of self-efficacy.

Hufferd-Ackles, Fuson, and Sherin (2004) studied how a teacher established classroom norms that help supported her reform math practices. They describe four levels of a "math-talk learning community." The levels begin at zero, with a traditional, teacher-directed format in which the teacher asks short-answer questions, and student responses are directed to the teacher. In level one, "getting started," the teacher begins to pursue and assess students' mathematical

thinking, focusing less on answers alone. In response, students provide brief descriptions of their thinking. The next level, level two, is called "building." At this point the teacher elicits and students respond with fuller descriptions of their thinking, and multiple methods are volunteered. The teacher also facilitates student-to-student talk about mathematics. The final level is "math-talk." In level three, students share responsibility for discourse with the teacher, justifying their own ideas and asking questions of and helping other students. At this level, the students require little direct instruction from the teacher, and therefore become more self regulated, which leads to increased self-efficacy (Zimmerman, et al., 1992).

Teachers must establish practices or sociomathematical norms that will benefit all students (Boaler, 2002). Promoting the use of mathematical language in discourse will create equity by allowing all students access to mathematics. As students become proficient in the academic language of mathematics, they become more confident and active participants in the math community.

High–press. Using high-press questioning during instruction is an effective teaching strategy in mathematics classrooms (Henningson & Stein, 1997; Mewborn & Huberty, 1999; Kazemi & Stipek, 2001). Effective questioning allows teachers to get at the core of student understanding, as well as presses the student to clarify his or her own understanding. Teachers who listen carefully and ask questions designed to press students to respond thoughtfully, are able to clarify misunderstandings as well as model correct wording. Mewborn

and Huberty (1999) advocated what some call a 'high-press' form of teacher questioning and discourse. They felt that teachers needed to ask questions that provoked thoughtful responses, not questions that required one-word answers. They concluded,

> Asking questions that will stimulate classroom discourse is a powerful avenue for achieving the goals of the Professional Standards (NCTM 1991). Giving students opportunities to explain their thinking and to listen to the reasoning of their peers has a profound impact on their mathematical thinking. Participating in a community of learners enables students to develop mathematical power and become confident problem solvers (p. 246).

There is a difference in the kinds of questions that press students to think through mathematical concepts (Herbel-Eisenman & Breyfogle, 2005). Herbel-Eisenman and Breyfogle defined two types of questions, funneling and focusing. Funneling questions lead students to the ideas that are in the teacher's mind, while focusing questions will press students to clarify their own ideas. The teacher listens to students and guides them, using the students' thoughts and ideas, not the teachers. When teachers use focusing questions, it requires students to be clear and articulate their perceptions so others can understand their thinking.

Classroom discourse, with students verbalizing their justification and reasoning to fellow students and to the teacher has also been proven effective in supporting student understanding. Kazemi and Stipek (2001) showed that there are differences in the quality of mathematical discourse. High press teachers

voiced confidence in students' ability, but also explicitly taught how to talk about the mathematics. The teachers in the study who practiced high-press questioning techniques gently pressured students to extend mathematical thinking and reasoning to other concepts. The teachers who used low-press questioning asked students to explain how they arrived at an answer, but did not press students into extending their conceptual understanding.

Modeling and practice. Along with pressing for meaning and comprehension, teachers must strive to model acceptable explanations and justifications (Walshaw & Anthony, 2008; Herbel-Eisenman& Breyfogle, 2005; Hufferd-Ackels et al., 2004; Henningson & Stein, 2007; Khisty & Chval, 2002). Teachers cannot simply teach vocabulary, put the words on a word wall, and expect students to comprehend meaning. The language of mathematics should be learned in context to become meaningful to students (Rubenstein, 2007; Khisty & Chval, 2002). Teachers must use mathematical language in their instruction and in discourse with students.

Limitations

Despite new research on effective pedagogy, there are many teachers who cling to the traditional way of teaching. Teacher perspectives differ from one classroom to the next, however, to create an equitable system of instruction, teachers must use pedagogical practices that are research based and effective for supporting conceptual understanding. National Council of Teachers of

Mathematics (NCTM) wrote *Principles and Standards for School Mathematics* (2000) to outline best practices for teaching mathematics. The complexity of the mathematics students must learn is much higher than teaching procedures and algorithms. Teachers must keep themselves informed of current research and use best practices to ensure equity for all students.

While I found many articles focused on language, and many articles on discourse in mathematics, there were few that connected the two concepts. Most of the research that involves academic language and mathematics are specifically written with ELLs in mind. Although the research on language acquisition is helpful when teaching vocabulary and discourse, there needs to be more studies involving the relationship between language proficiency, equity, and self-efficacy in mathematics classrooms.

There is a danger when focusing on one specific practice of teaching, that the teacher will lose sight of the underlying goal (Adler, 1999). Teachers must be cautious of placing too much focus on the words themselves and losing sight of the mathematical concepts. Students will attend to the things they feel that the teacher values. When the words become the focal point, the mathematical concepts may be lost. The language of mathematics in only one piece of the puzzle and students need all of the pieces to be successful mathematicians.

Conclusion

Classrooms in our country are increasingly diverse and include students from many different cultures. Even within the English speaking population,

students have different language experiences and cultural backgrounds. Teachers must attend to the diverse backgrounds of all students in order to create an equitable classroom environment. One way for teachers to reach all students is to support the development of proficiency in academic language.

The academic register is important to student success in school. Teachers, textbooks and state assessments all use this formal register of language. When students do not have previous experience with academic register, their teacher's instruction, book lessons and tests may not be comprehensible, and they will struggle academically. Understanding academic language will help students have increased academic success.

Mathematics uses its own register of academic language. There are words used in mathematics that are rarely used outside of a math classroom. Additionally, there are many words students have heard in other contexts, but have different meaning in mathematics than in other circumstances. Teachers must take care to address vocabulary and language that is specific to mathematics, and be cautious of misconceptions about how mathematical language correlates with language in other contexts.

One way for students to become more proficient in mathematical language is to use it in classroom discourse. Teachers can guide students to deeper understanding of mathematical concepts by facilitating appropriate language in discourse, using and modeling high-press questioning, and by establishing norms that emphasize student accountability and self-regulation. Learning how to

communicate mathematically with others will help students build confidence and increase motivation.

As confidence grows, students become more intrinsically motivated to participate in mathematics. The students become increasingly responsible for their own learning and are less dependent on the teacher, reinforcing feelings of self-efficacy. Students who have strong feelings of self-efficacy are more likely to tackle novel or difficult problems. As students experience success, they are more willing to attempt increasingly challenging tasks.

Creating an equitable classroom environment is not a 'one size fits all' chapter of a pedagogy textbook. Although I have laid a solid, research based argument for supporting academic language proficiency, I make no claim that teaching language will magically cause all students to have success in school. Supporting academic language proficiency is one practice of many that will help students build self-efficacy and realize their full potential in academics.

Chapter 2: Methods

Setting and Participants

Participants were sixth graders from a K-6 school on the outskirts of a middle-sized school district in the Pacific Northwest. There were 22 students in the classroom. The class was a heterogeneous group, with approximately 40 percent qualifying for free or reduced meals. Three students qualified for special education services and an additional three students qualified for Title 1 services.

All students were interviewed initially, and six students were chosen for second interviews, based on responses on self-efficacy survey compared to short essay question responses as well as their discourse in class. I collected data on the whole class, mainly for the purpose of comparison but also to protect anonymity. Pseudonyms were used for all students and teachers.

The adopted curriculum used in this class was Math Connects (Glencoe, 2009). Because this curriculum is largely procedural, I supplemented with Connected Mathematics Project (CMP, Pearson, 2006) for inquiry-based problem solving practice. Pre-test and post-test questions were taken directly from the question banks of these two curricula to ensure that other teachers could easily reproduce the materials in their own classrooms.

Data Collection

The majority of the data I collected was qualitative. I incorporated whole group instruction teaching strategies, group-work (Cohen, 1994), and individual

work time. To collect data, I used audio recordings of whole group and group/partner work to analyze the content of student discussions and depth of mathematical understanding. I used a survey to assess self-efficacy in mathematics at the beginning of the study and again at the end of the study to assess positive or negative growth. I interviewed several students, using audio recording and transcription. I also kept informal field notes; writing my thoughts about the day's lesson, student comments that were not audio recorded, and other ideas that occurred to me during the day in a notebook. These field notes helped me recall my impressions of student attitude and demeanor as well as math related comments that were made outside of the math class.

Survey. A survey that asked students to measure different aspects of mathematical ability was used to assess self-efficacy. The survey consisted of ten questions and four statements that students answered using a 5-point Likert scale (a scale in which students rate agreement or disagreement on a 1-5 scale) (see Appendix B). The survey asked students to rate themselves on their attitude toward mathematics, mathematical ability, their knowledge of mathematical procedures, knowledge of mathematical language, past experience in mathematics, and probable achievement in mathematics.

On the survey, the ten skills I included covered skills about which a sixth grader would likely have self-knowledge, including confidence in basic math facts, word problems, geometric skills and vocabulary. I gave students in my classroom the survey during week two of the study, as the class settled into a

basic routine, and again at the end of week seven. I asked students to score themselves on a one to five scale, one being the lowest confidence, and five being the highest. I gave the survey early in week two because I wanted students to assess themselves before they had much experience practicing using language and discourse in mathematics. Using a Likert scale allowed me to determine growth over the seven weeks of the project. Using the surveys allowed me to get student responses about their feelings of self-efficacy and about how confident they felt with the vocabulary and language of mathematics. I compared the scores in each category from weeks two and seven to determine if there was any measurable growth in self-efficacy. This data was used to help me identify any change in the students' feelings over the course of the quarter

Audio recording. I audio recorded randomly selected groups during weeks two and three, then re-assembled the same groups again and recorded during week six and seven. Audio recordings also allowed me to assess discourse changes between week one and seven, and were analyzed very carefully for exact dialogue. Audio recordings were transcribed and coded, with student use of mathematical vocabulary in mind.

I recorded lessons several times a week and during group work. Because of the time constraints of this project, it was unrealistic to record all lessons. Recording allowed me to listen to the interactions between students. During student interactions, I listened for correct use of the mathematical vocabulary in discussions and explanations and was able to determine whether there was more

mathematical language present as the quarter progressed. The discourse was also analyzed for conceptual understanding and statements of confidence or lack of confidence in mathematical ability.

Field notes. I kept a daily journal with activities, conversations, reflections, and ideas. I used a spiral notebook, and attached loose notes or sticky notes into the spiral notebook with dates and student initials, which allowed me to keep track of student discussions and dialogue with me and other students. This gave me a record of interactions on a daily basis, and helped me reflect on lessons and make adjustments based on student needs. Due to possible inaccuracies inherent in writing from recollections, I did not attempt to make any claims of growth based on these notes alone.

My journal allowed me to record thoughts, ideas, questions, and reflections at times when I did not record class sessions. There were also times during the day when I had ideas about how to present information or how to respond the next time a situation occurs. I kept track of student questions, positive and negative comments and mathematical language used outside of the scheduled math time, when no recording was taking place.

Student interview. I chose six students to interview, based on the responses of the self-efficacy surveys. I audio recorded and transcribed each student interview, asking between five and ten questions (see appendix C) that focused on the students' previous experiences and feelings about math. I then

chose three of those interviewees to participate in another interview, based on their responses in the first interview. All interviews were limited to less than fifteen minutes to keep students engaged and responsive. Interviews occurred during week six and again during week eight, to search for changes in feelings and to ascertain what practices the students found instrumental in differences in their feelings of self-efficacy in mathematics. The questions asked during week eight were more directly focused on seeking a connection between mathematical language and self-efficacy.

I used student interviews to search for common themes in language use/comprehension and between the different levels of self-efficacy. As I analyzed the recordings and transcriptions, I was watchful for positive or negative changes and made every effort to adjust my teaching to support growth in self-efficacy. I asked students general questions about their perspective of perceived growth and what they felt had helped them grow. I allowed students to direct much of the course of the discussion and encouraged them to speak freely.

Analysis

The self-efficacy survey consisted of ten statements that the students rated by choosing a level of agreement or disagreement, from one to five. The survey used a five-point scale that allowed me to obtain a mean for the individual as well as the group. I gave students the same survey at the end of the project to ascertain changes in self-efficacy and.

The audio recordings were transcribed and coded. I searched for common themes as I coded, but the emphasis was on student use of mathematical language and mathematical confidence. I analyzed this set of data for the number of words, new vocabulary, and the correct use of the language. I paid careful attention to self-efficacy related utterances, tracked participation, willingness to explain and justify, and statements of confidence, or lack of confidence.

My field notes helped triangulate other data as well as helped me keep track of interactions outside of the math time or at tables not being audio recorded. I recorded student comments, parent comments, and my own thoughts about the lessons. I looked for a relationship between mathematical language proficiency and self-efficacy, and found that tracking my reflections allowed me to be more aware of my teaching practices and reminded me that understanding math concepts is the goal, not memorizing the words.

Student interviews allowed me to privately ask about student feelings. I allowed students to direct the conversation, but remained focused on the foundations of their feelings of low or high self-efficacy. I looked for background information about student feelings in mathematics, their positive and negative experiences, and what they thought about math in general.

Limits of Conclusions

Qualitative studies are subjective by nature. There is no specific script for what I said to students during any given lesson; therefore, there are no consistent variables to measure. I have tried to account for this by having all of my

transcriptions verified and reviewed by peers for accuracy. I also used written work, assessments, and student surveys to triangulate my data.

Time constraints were a major limitation in this project. The window for collecting data was only eight weeks. Because of the limited time, I gathered data at regular intervals and stuck very closely to my timeline. This ensured that I had information from the beginning, middle, and end of the project, without uneven spaces between lessons and data collection.

During this project, I acted as the teacher, but also the researcher. There is a danger that my relationship with students altering my inferences and notes. I attempted to lower the possibility of bias by having my data and notes verified and reviewed by peers for bias and accuracy.

Student surveys were also a threat to validity because student self-reflection is not always consistent or accurate. There is a distinct possibility, when eliciting student responses, that students were not honest or chose an answer thinking it to be funny or that it was the 'right' answer. I spoke to the students before the pretest and posttest and reminded them to think about their responses and answer as honestly as possible.

Because of the specific context of my classroom, the results may not be generalizable to all classrooms or all students. I do not seek to show a causal relationship, but will focus on the trends of student engagement and self-efficacy. My goal is to reveal the connections I see within my own classroom context and to detail these connections in enough detail so as to allow others to determine generalizability to their own contexts and classrooms.

Chapter 3: Research Findings

Overview

Current research suggests a connection between language proficiency and academic achievement (Krashen & Brown, 2007; Matthews, 2008). I conjectured that because mathematics uses many words and phrases not used in everyday language, students might struggle because of a lack of proficiency in the language of mathematics. When students are not able to understand the language, they are unable to communicate mathematically, comprehend the understanding of others, or participate in meaningful discourse, which has been tied to students not having equal access to the mathematics. In this study, I attempted to support mathematical language proficiency in student discourse, believing that as students become more proficient in the understanding and use of mathematical language, they would be more able to participate in meaningful discourse.

Current research has also shown a connection between self-efficacy and achievement (Zimmerman et al, 1992). I conjectured that increasing understanding of mathematical language would allow students more access to the mathematics and, therefore, students would feel more confident in their mathematical abilities, in turn increasing achievement on assignments and assessments. I reasoned that as students participated with others in mathematical discourse they would become more confident in their ability to communicate their understanding and comprehend the understanding of others, which would increase self-efficacy. My goal was to try to identify whether a relationship existed

between increased language proficiency and self-efficacy. Additionally, though not the focus of this study, I expected that with an increase in self-efficacy, there would be improved achievement in mathematics as well. To test my conjectures I developed a survey, collected student work, audio recorded classroom discussions, and interviewed several students.

By analyzing data collected over eight weeks, I determined that there was growth in mathematical language use and understanding. The number of mathematical words students spoke increased over the course of the study, and the language used by students during discourse became progressively more complex. I also found a small increase in student reported self-efficacy, as determined by survey scores.

Classroom setting. The classroom is one of two, self-contained, sixth grade classes on the rural outskirts of a middle-sized school district. Most of the classrooms in the school are portables. There is standard educational technology in every classroom, such as computers with Internet access, document cameras, and projectors.

There are 43 students in the sixth grade. Approximately forty percent of the students are from military families, with several parents currently deployed. Many of the military students are highly mobile, and have moved three or more times since beginning school. Twenty-two students were in the classroom in which I conducted the study, but only twenty were included in the data. Several

students moved and two joined the class during the study. The data from these students was not included in the analysis.

The students in this class have struggled in both mathematics and reading throughout their earlier grades. My class began the school year with 41% of the students having passed the math MSP (a summative state assessment), and 63% at grade level on math MAP tests (a computer based test of student knowledge). The students in this class scored below grade level in reading, as well, possibly contributing to the lower math scores on the standardized tests.

Until last school year, the district had been using Connected Mathematics Project (CMP, Pearson, 2006) as the adopted sixth through eighth-grade math curriculum. CMP focuses heavily on complex problem solving. The curriculum consists of mostly word problems, asking students to reflect on their thinking during and after lessons. Though it is no longer the adopted curriculum, I continued to use CMP in my classroom for group-worthy problems (Cohen, 1994).

Recently, the school district adopted Math Connects (Glencoe, 2008) for all grades through middle school. Math Connects includes problem solving, but centers mainly around building procedural knowledge. I used Math Connects for procedural practice, with the expectation that students could explain how and why the algorithms were effective.

Instructional approach. I have a Bachelors degree in Elementary Education, and a minor/endorsement in Teaching English as a Second Language

(TESL). Much of my pre-service, student teaching, and substitute teaching experiences were in ESL classrooms between first and eighth grades. I have seen first hand the struggle students have when they do not understand the language of the subject being taught. This experience showed me that when students do not comprehend the language, they do not have equal access to the content.

I have been teaching sixth grade for four years. During my undergrad work, an 'I do, we do, you do' method of teaching was strongly encouraged, and I spent the first two years of teaching using this format 'successfully' in my classroom. Since beginning my masters' coursework, I have learned the importance of teaching students to think critically, problem solve, communicate mathematically, and have since incorporated mathematical discourse into my classroom norms. This change was easily established, in part, by reversing my teaching methods. Most often, I began class with an explanation of student learning goals and a quick reminder of a previous learning goal needed for success in the new lesson. The lesson that followed was more 'you do, we share, I summarize' format that was a good fit for the class.

I used very little direct instruction in mathematic language and vocabulary. Based on my background in language acquisition, I know that children learn new language by hearing it used and using the new language themselves, and not by simply memorizing vocabulary words. In my math classroom, I explained new terms and reinforced previously learned terms and had students use a four-square model (see appendix A) in their notebooks, but did not use vocabulary worksheets, quizzes or tests. I used the language of mathematics

in my teaching, asked that students use correct terms and language in their explanations, and gave positive attention and reinforcement when I heard the language being used correctly in group or partner work. When mathematical language was used incorrectly or oversimplified, I rephrased the student's statement and replaced the incorrect term with the correct one in my responses.

I was always careful to encourage students and provided a safe place to try out new understanding and language. Mistakes were common, and were viewed as an opportunity to learn. I felt that a safe environment for errors was a necessity for student growth in mathematics. My hope was that as students became comfortable in the math classroom, they would become more self confident and therefore more willing to participate in classroom discourse.

Results of Data Collection

Mathematical language. Early in my teaching career, I assumed that students would have a basic understanding of the mathematical terminology and language used in previous school years. I jumped into lessons as if the students had mastered everything in grades one through five. My check of background knowledge was something like, "You remember this, right?" I soon realized how naïve this assumption was. One day, a student told me that she did not understand the problem. I asked her to read it to me, thinking that once she read it aloud, she would figure out what she did not understand. She read the problem, and confronted me indignantly with, "What the heck is a sum? We never learned that!

Why don't they just tell you what they want you to do?" I had to stop and think about how I was teaching students math. Do the words matter?

When I began my masters program, I learned how important verbalizing mathematical understanding is to individual growth as a mathematician. I realized there is a distinct connection between communicating in mathematics and communicating in a new language. When one does not or cannot use the language, he/she does not have full and equal access to either the language or the content of a subject.

Due to the time constraints of this study, I hurried through the basic classroom and mathematical norms with my students. A normal class period began with students going over homework, and explaining to the others at the table how and why they got the answers that they did. I then went over background information and any new vocabulary, using a four square model (appendix A). I read a problem or two, to determine if students needed more clarification, then students worked together to complete assignments. At the end of the class period, several students explained their group's thinking to the rest of the class.

I recorded group discussions during homework check-in and class time, to determine what, if any, mathematical language was being used without my prompting. Recordings were made of random groups during homework discussion time, and then group discussions as I walked around the room during class work time. Class sessions were recorded during weeks two and three, then again during weeks six and seven. I did not record during weeks four and five,

primarily because of the overload of transcribing, but also found that it helped me identify differences between the early recordings and later recordings more easily.

I recorded the first homework-check one week after the first day of school. Students went through each problem, reading it carefully, and then giving their answer. The mathematical language they used was basic and did not stretch past elementary operations. Additionally, as I coded this particular transcription, I realized that one of the problems was an order of operations problem that required students to use operation symbols to make a sequence of numbers equal to another number. I had to go back and change the coding for the entire problem; they were not using the language, simply labeling the operations.

The students in this early group used words for basic operations, such as add, plus, and minus, but used the same terms for the mathematical process that they used, saying 'plussed' or 'minused'. They showed understanding of the word 'sum' in a problem when giving the answer, "9 plus 7 plus 3 equals 19", but did not use the word 'sum' in their discourse. The only other word students used consistently without prompting was 'equals', again, an elementary term, but one that is useful throughout mathematics.

During class-work time, the early use of language was also very basic. Much of the students discourse involved elementary operations, but little else. Several students used the word 'timesed' instead of 'multiplied' or 'minused' instead of 'subtracted'. Repeatedly, students referred to their answer to a problem by saying, "I got…" instead of using the words sum, product, or equals.

Johnny: "We got 7 quarters and 3 dimes and he (Andy) got 1 dime."

Sadie: "I got 7 quarters, which is a dollar 75 and then 3 dimes is 2.05."

This trend was consistent during weeks two and three for the entire class. As I listened to and transcribed student discussions, I found that there was a similar pattern of mathematical language use in every recording; students did not use language beyond numbers and basic operations during group discussions. Students were more likely to show other members of the group what they had done to solve a problem than to communicate verbally. I did not identify any particular student that used mathematical language in discourse more than any other student did, nor could I distinguish any noticeable difference in individual student understanding of the language or terminology during the first two weeks of the study. I used random grouping (choosing group members using name cards) so groups changed every two or three days, but the language pattern stayed consistent. I continued using the terminology in my explanations, and also began to rephrase student explanations, using mathematical language and pressing students to use mathematical language.

The recordings from weeks six and seven showed a small but definite increase in the use of correct mathematical language and comprehension. Many students had begun using the words 'multiplied' and 'added' instead of 'timesed' and 'plussed'. In another lesson, using frequency tables, line graphs, and bar graphs, students did not use terminology or special language in-group discourse, but did use correct terminology when labeling parts of the graphs, such as axis, coordinate, horizontal, and vertical, when explaining to me. Additionally, in the last two weeks of the study, I found growth in understanding of terminology.

As I transcribed and coded the recordings of week two and three class discussions, I identified few mathematical words. From week two until week three, I saw an increase in student use of mathematical language, but I felt that the words I heard during group work were still mostly labels for basic operations. However, the increase in the use and understanding of mathematical language was strongly evident in weeks six and seven, as evidenced by a student's comments in an informal interview.

> T: So, is it helping you in math, to slow down and explain what all of those parts and pieces of the math problems mean?
>
> Kim: (Nodded) And doing it again, 'cause last year, I didn't really know what place value was or an expression or equation and stuff.
>
> T: So, now you understand what it means when the problem asks for products and sums.
>
> Kim: Yeah!

Kim began the school year saying words like 'timesed', 'minused', and 'plussed' and by week seven, was consistently saying 'multiplied', 'subtracted', and 'added'. I heard other students use these mathematical words, such as expression and equation, many times during group discussions as well as during both sets of interviews.

I found that the mathematical language utterances increased greatly when students spoke to me, rather than when they were working in groups. They understood the language and vocabulary, but were not consistently using it when speaking only to other students. When speaking to me, students invariably used the language that I used. This pattern of discourse was consistent throughout the transcripts from weeks six and seven.

The growth in student use of mathematical language in discourse was evident over the course of the first eight weeks of school. Students seemed to become more proficient using and understanding the vocabulary and terminology, but were more likely to use the language when talking to me than to one another.

My hypothesis was that supporting mathematical language proficiency, or the ability to talk about the math, would help students feel more confident in their ability to do the math. I supported the use of mathematical language in discourse by emphasizing new vocabulary, consistently using mathematical language in my instruction, directing the use of correct terminology with subtle corrections and rephrasing of student language, and using positive feedback for using solid mathematical language in group discourse. There was a definite increase in student use of correct terminology as well as participation in group discourse and willingness to share ideas with others. I observed an increase in the actions that I felt indicated self-efficacy, but could not be sure it was the result of increased proficiency in mathematical language.

Self-efficacy. Self-efficacy is a term first used by Albert Bandura, a professor of psychology who specializes in social cognitive processes. Bandura (1997) defines a student's perception of his/her ability to accomplish tasks and goals as perceived self-efficacy. Bandura contends that this belief influences one's actions, effort, perseverance, resilience, and realization of goals. Consequently, the beliefs associated with individual ability often determine the outcomes before any action has taken place.

Students who exhibit strong self-efficacy are those who have confidence in their ability, are able to set goals, can confidently solve problems, and participate proactively in their own learning. Studies have shown that students with a high sense of efficacy have greater persistence, effort, and intrinsic interest in their learning and academic achievement. (Ben-Yeheda et al, 2005; Schunk, 1984; Zimmerman et al, 1992). Due to the time constraints of this study, I chose to focus on student confidence in their mathematical and problem solving abilities, and tried to ascertain student feelings about math in general, as well as their general feelings of self-efficacy.

During the first week of class, students were asked to write one-paragraph essays about mathematics, so that I could get a general idea about their feelings in mathematics. The topic was either 'I Love Math' or 'I Hate Math'. I chose 'love' or 'hate' because I wanted students to think about their relationship with mathematics and try to explain their feelings. I also wanted to understand whether students were more extrinsically or intrinsically motivated. While three students wrote that they hated math, the others wrote that they loved math. Many of the students that loved math did not test at grade level, hinting to me that it might not be only scores that made students like mathematics or feel confident in their mathematical abilities.

The three students who wrote that they hated math had struggled in math for several years. They all stated that the math was becoming too difficult. One student wrote, "…Math is so many numbers!" Another student similarly stated, "It is difficult to keep track of so many numbers". The one reason for difficulty in

mathematics that was common to all three papers was that they hated math because of division. All three students who claimed to hate math stated that the division was too hard. This connection between ability to perform a standard algorithm and a feeling hate toward math in general showed a distinct lack of self-efficacy. They did not see division as a challenge to be worked on and overcome; they simply decided that math in general was too difficult.

The students who wrote that they loved math listed several reasons. The main reason that was noted by most students was that they were 'good at math' or that 'math was easy' for them. Several students reported that they liked math because it would help them later in life or would lead to a good job. One student who frequently struggled, Sadie, wrote that she loved math because 'If you don't know how to count and get an 'F' that could be a problem for you". Her underlying message seemed to be that if you do not like math, you will not know how to do it, and will fail, instead of the more common student response, which was that if one does not know how to do math, math is not liked. When Sadie was interviewed, her essay statements were consistent with her verbal statement.

> T: So, Sadie, you are feeling pretty confident with your math right now?
>
> Sadie: mmhmm
>
> T: Why? What is going on in math that is helping you feel like… you've got it figured out?
>
> Sadie: I-I-I'm confident and I just feel good about it. My last year in 5th grade, um, I liked it a lot. It's my favorite subject, it is, and I've had A's and B's in it.

> T: So, if you get some problems wrong, when you make mistakes on papers or practice, and you do not understand, or you can't figure it out, what do you do?
>
> Sadie: Ask.
>
> T: And what does that make you feel like?
>
> Sadie: I just feel good about it. Half the time I get it and half the time I don't. I get them wrong and then the next time, I get them right. I just go over them again and again and again and again and again.

Sadie felt if she liked math, she would be good at it and would get good grades. She mentioned the fact that it was her favorite subject and that she received A's and B's in math last year. Sadie did not seem bothered by the fact that she consistently made many errors, simply stating that she would go over the problem until she got it right. There was no doubt in her mind as to whether she would figure the problem out; it was just a matter of practicing more. I identified this persistence in problem solving as one of the traits of self-efficacy when I coded the essays. I realized that it was not always the successful math students who demonstrated the highest self-efficacy.

The consensus from most of the students who scored at or above grade level was that they loved math because it is fun or easy. In contrast, students who commonly struggled and claimed to love math gave reasons that included the importance of counting, keeping track of money, or telling time. These were skills that they felt were important to their futures and therefore, they needed to be successful at those skills.

Early in week two of the school year, students were asked to complete survey that focused on their perceived ability in mathematics (appendix 3). The

same surveys were given during week seven. Ten survey questions were chosen to include perceptions in several areas of mathematics, including procedural ability, word and language ability, algebraic ability, and geometric ability. I chose these categories because they covered the basics of mathematical comprehension and I knew students would have had experienced each type of mathematical ability. I was confident that students would be able to rate their confidence or self-efficacy in each ability. I felt that asking fewer questions allowed me to have a window to student thinking without overwhelming them with so many things to consider that they might choose responses randomly, simply to finish the survey.

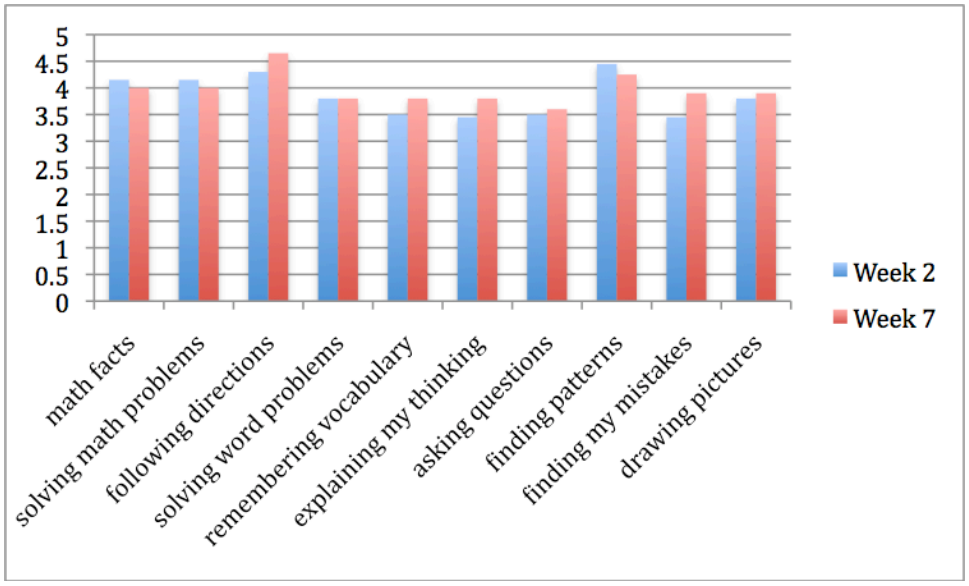
The first category included three questions regarding ability to perform procedures. Students were asked to score themselves from one (lowest) to five (highest) in their ability to correctly complete basic math facts, to correctly use basic operations to solve standard algorithms, and to follow directions. I decided that following directions fit best into procedural competence, since critical thinking is usually not necessary for following steps or procedures.

When the survey was given in week two, students consistently scored themselves higher in procedural competence than in any other category, with most of the students self-reporting a score of three, four, or five. Many of the grade level and above students were very confident in this category, giving themselves a five in all sections. The survey in week seven showed a general decline in procedural scores, with several of the more successful math students dropping from fives to fours in basic facts and operations, or scoring themselves at a five in

basic math facts and dropping to a four in algorithms. Following directions remained high for almost every student, with only two scores of three and the rest fours and fives.

The second category was algebraic sense. Students rated their ability high in finding patterns. Most students rated themselves either a four or a five in this category in both weeks two and seven, with a slight drop in week seven. The class average in this category of algebraic sense was higher than four on both surveys. The focus of the first eight weeks of class has been on algebraic expressions, patterns, and graphing. I wondered whether students felt that they had overestimated their abilities in finding patterns, however, they remained confident in their algebraic competence from week two through week seven. I assigned four abilities to the third category, which were the language abilities. I asked students to score themselves in their ability to solve word problems, remember vocabulary and mathematical language, explain thinking, and asking questions. The scores were consistently lower in this category than in the others on both surveys. Several students reported that they either disagreed or strongly disagreed with the prompt, 'I am good at explaining my thinking', and even more stated that they were not at all confident with word problems.

Table 3.1 Results of Self-efficacy Survey; class averages



When asked to score confidence in their ability to ask questions, students scored themselves higher in week seven than in week two. This increase seems to indicate that they were more confident in their ability to ask questions about the math. Students scored an average of three and a half in explaining their thinking in week two, and that score rose slightly during week seven, which seemed to contradict my observations. In my field notes, I wrote that I felt that students seemed more able to explain thinking and communicate understanding in week seven than in week two. I am unsure whether this discrepancy was due to students misunderstanding what I meant by explaining thinking or if they felt that explaining their thinking was more difficult than they originally believed.

Overall, students reported a small gain in most categories of the self-efficacy survey from week two to week seven. There were, however, several of the grade-level and above students who lowered their scores in a number of categories on the survey in week seven. When I questioned these students, one

stated that the math was harder than she originally thought, and the other (Andy) sheepishly admitted that he didn't really think about his responses on the first survey, and that he had tried to think harder on the second survey.

I have several ideas of my own about these students' drop in scores. It is possible that because students are being asked to explain the 'why' of solving a math problem, not simply the procedure that they had used, they felt less competent. I also wondered if being asked to use the correct terminology and vocabulary made mathematics more challenging than in previous years. If a student's previous mathematical experience had been to work independently and simply solve procedures, he/she felt confident in mathematical ability, but when asked to explain the how and why so that other students could understand, the student felt less confident. I also wondered whether there were other students like Andy who may not have taken the survey seriously. I conjectured that many of my students may have assumed that if they had received good grades in math in the past, they felt that they were good at math.

At the end of the study, I informally interviewed several students. I found that none of the students could explain what made them think they were better at math. When asked to explain what had helped them become more confident in their mathematical ability, several students replied, "I don't know". When pressed to decide what had helped them to be better mathematicians, one student, Ally, simply stated, "My brain".

Originally, as I read the early interview transcripts, I was looking and coding for students' declarations of confidence and, because of my observations,

felt that their self-efficacy had increased. Students claimed to be better at math in the seventh week than the in the second week, but when asked how they knew that they were better, they could not attribute their growth to anything in particular. Students did not relate this increase in self-efficacy to increased understanding in mathematical language, instead acknowledging the increase in both self-efficacy and language proficiency separately. Several students said that practice had made them better; others simply stated that they did not know. I wondered if I had asked the right questions. I did not want students to give me answers that they thought were 'correct', but also wanted to guide them in the direction I wished to go, which was for them to try to identify what had caused their feelings of success.

After transcribing and coding the interviews from week seven and finding that students were not verbalizing an increase in their confidence, I decided to re-interview several students in week eight. I intentionally asked about their feelings in mathematics, if they felt that they were better at math than earlier in the quarter, and why they thought that they were better (or worse). Again, I tried to let students talk freely, but I was more intentional about making sure I dug into the key issues of self-efficacy and mathematical language. As I asked key questions (appendix 5) and got more honest and direct feedback from students, I still found little verbalization about becoming more proficient in mathematical language helping increase confidence in mathematics.

One student, Andy, scored himself lower on the second survey, but verbally stated that he felt that he was good at math. In his first interview, he said

that he did not know why he was good at math, or why he had scored himself lower, even though he is one of the more capable math students in class. In the second interview with Andy, he admitted that he had not really thought about his responses to the first survey. He knew he was good at math so he scored himself at a four or a five in every category, except for explaining his thinking. He conceded that he said he was not good at explaining because he does not like to work with other students, not because he thought he was bad at explaining. He went on to say that when he had completed the first survey, he just wanted to finish it, but when he took the second survey, he had thought more about his responses.

Another student, Kim, was also interviewed twice. She was a more energetic student, often the first to raise her hand, whether she had an answer or not, and always wanted to actively participate. On the first survey, Kim scored herself fours and fives for every category that was not language oriented. In the four language categories, she gave herself threes. When asked about this, she said that she knows what she is thinking, but cannot say it. I pressed a bit more and she stated that she "just liked doing the math problems, not word problems and stuff", but did not connect her dislike of word problems to problems with the words. I got the feeling that she did not like the word problems or explaining her thinking because it takes longer, but could not be entirely sure.

On the second interview with Kim, we discussed her increase in scores on her week seven survey. She had rated all categories at fours and fives, with the exception of vocabulary, which was still a three. When asked about her growth,

she attributed it to practicing on a math website my class subscribes to which allows students to practice procedure problems at home. I asked her about the increase in her confidence in word problems and explaining her thinking but she was unable to tell me what had helped. During her second interview, Kim was more able to articulate her self-efficacy.

> T: so, I was wondering what the difference is now compared to earlier.
>
> Kim: My teacher last year went really fast and even though I was in an extra math class in the morning and in the afternoon, all we did was division and multiplication
>
> T: so all you did was practice math problems?
>
> Kim: mmmhhmm
>
> T: So, is it helping you in math, to slow down and explain what all of those parts and pieces of the math problems mean?
>
> Kim: and doing it again, 'cause last year, I didn't really know what place value was or an expression or equation and stuff
>
> T: so now you understand what it means when the problem asks for products and sums?
>
> Kim: yeah
>
> T: you understand order of operations…
>
> Kim: and luckily for everyone else, my teacher from last year retired

I intentionally included the last statement because it illustrates the student's lack of concern for the topic our conversation, thought she agreed to the interview. She stated that she was doing so much better than last year, but did not know why. I kept pressing her and she decided that the main reason she thought she was better was that I taught more slowly, gave students time to think, and that I reviewed a lot. She then acknowledged that understanding the language might

have helped, but did not connect her increase in self-efficacy to an increased understanding of the mathematical vocabulary, instead thinking it was simply that we had gone slower and that she had had more review. As evidenced by one student in this short transcription, many students typically were not aware of their growth in mathematical language nor did they seem to connect their increased knowledge of the language to increased confidence in mathematical ability. I then addressed the increase of mathematical language specifically.

> T: I noticed when I was listening to tapes of our class times that you are using words like multiply instead of timesed and added instead of plussed.
>
> Kim: (laughs)
>
> T: So, why?
>
> Kim: I don't know, I suck at doing the regular math problems.
>
> T: What kind of problems do you do right?
>
> Kim: I don't know!
>
> T: Are you just going too fast?
>
> Kim: NO!
>
> T: Are you not paying attention to what they say?
>
> Kim: Last year I went fast on the tests a lot, but I still got answers right.
>
> T: What do you think would help make it even better? Because I would love to see you score yourself at five all the way across the survey.
>
> Kim: I think that's impossible
>
> T: Why? Do you know your math facts?
>
> Kim: Yes
>
> T: Can you solve word problems?

> Kim: Yes, but I don't do it like some people sometimes, it messes me up. Like I can't multiply 9 times 6, I have to multiply 9 times 7 and subtract 9.
>
> T: Do you hear how you are explaining? You are using words like multiply and subtract!
>
> Kim: I still mess up
>
> T: You are doing great! And you know you are doing ok, you scored yourself at a 4.2 average on this survey.
>
> Kim: Last year, I got all twos on my report card. This year, I think I can do it better.

This excerpt illustrates the use of mathematical terminology that had become part of the student's daily discourse. Kim was unaware that she had used the mathematical vocabulary until I brought it to her attention. She also expressed increased confidence that she would be more successful in math this year than in previous years. Both pieces of my study question were evident separately, but the student did not make a connection between vocabulary proficiency and her growing self-efficacy.

After talking to students, I realized that rather than relying on data from the surveys, the sentence starters may have been more revealing. Although most students responded with one or two word answers, the responses were concise and illustrated how students perceived a connection between mathematical language, academic success and their feelings about math in general. When asked to complete the sentence, "When I know what the words in the problem mean I feel…". Most students answered that they would be happy, relieved, more confident, great, comfortable, or even 'epic'. When asked to complete the sentence, "When I do not know what all the words in the problem mean, I feel…".

Students responded that they would be confused, frustrated, and worried. One student even said that he would feel like crying. Although it appeared that students had a beginning understanding that there is a connection between knowing the mathematical language and their confidence in mathematics, they were unable to verbalize that connection. Even though students were unable to articulate a relationship between their increase in mathematical language proficiency and self-efficacy, I heard students using language that is more complex in their discourse and could hear the increase in confidence that was evident in with their use and understanding of the language.

Summary of Findings

Through this study, I found that there was an increase of the use of mathematical language over the course of the first eight weeks of school. I believe that this increase is a result of classroom norms, teacher support of and use of the language of mathematics, positive reinforcement and encouragement when language was used by students and students' feelings of safety in using new mathematical language in the classroom.

There was an overall increase in self-efficacy between weeks two and seven. Specifically, most students reported that they were more confident in the language-oriented categories than they had been in the beginning of the quarter. Two of the more academically successful students recorded somewhat lower scores, but reported that at the beginning, they were so confident in their math

ability that they just marked high scores on everything without really thinking it through.

Students were unable to articulate what had caused the increase in self-efficacy. When asked pointed and leading questions, students answered in the affirmative, but I cannot say that they truly knew what had helped them increase their self-efficacy. The students may have been able to identify a connection if I had been more deliberate in pointing out when they used or comprehended the language and linked the language directly to self-efficacy.

I found that as students moved into the second week of the study, their conversation was riddled with debasing comments about their ability to solve problems and learn new mathematical concepts. Students claimed that the problems were too hard or more commonly declared, “I don’t get it”. My week 7 transcripts did not contain any of these negative comments. Students asked others to show them how they had done a problem, but I no longer heard the lack of determination to try difficult tasks. I know that students were more capable of communicating mathematically at the end of the study, but this change in dialogue may have also been due to established classroom norms. These changes could be the result of being able to communicate more effectively, but I cannot determine if the increase in ability to communicate is due to classroom norms or to mathematical language proficiency.

Finally, I found growth in both language proficiency and self-efficacy over the course of the study. I observed my students using mathematical language in their discourse with each other and with me. I saw students acting more

confident. They no longer put themselves down or use self-defeating words. They were excited and willing to share their ideas with the class.

Student reported self-efficacy also increased. I do not claim that my short student survey dug deeply into student feelings of self-efficacy, however, on the surface students reported that they felt better about their ability to perform specific skills and tasks. I noticed that students enjoyed mathematics more, were more likely to participate and share, and were more likely to verbalize understanding or lack of understanding with the class. Furthermore, on the survey, students expressed that when they knew what the words and language meant, they were more confident in math.

Another plausible explanation for the increase in the proficiency in mathematical language and in student self-efficacy was the classroom norms established early in the school year. I encouraged open, constructive dialogue and expected students to engage in group discussions. Students were encouraged to ask for clarification and to explain themselves to those who had questions. It is likely that this norm allowed students to become more confident about speaking, listening and engaging in mathematics.

Chapter 4

Conclusion

Classrooms in our country are increasingly diverse and include students from many different cultures. Teachers must always be aware of the diverse backgrounds students in order to create an equitable classroom environment. One way for teachers to reach all students is to support the development of proficiency in academic language.

Academic language is essential to student success in school. Teachers, textbooks and state assessments all use this formal register of language. Understanding academic language will help students have increased academic success.

Mathematics uses its own register of academic language. There are words used in mathematics that are rarely used outside of a math classroom as well as words that have different meaning in mathematics than in other circumstances. Teachers must be careful to address vocabulary and language of mathematics, and be cautious of misconceptions in student understanding of mathematical language.

One way for students to become more proficient in mathematical language is to use it in classroom discourse. Learning how to communicate mathematically with others will help students build confidence and increase motivation. As confidence grows, students become more intrinsically motivated to participate in mathematics. The students become more responsible for their

own learning and are less dependent on the teacher, reinforcing feelings of self-efficacy. Students who have strong feelings of self-efficacy are more likely to tackle novel or difficult problems.

Language. Research shows that in order for students to succeed in academics, they must understand the language of instruction (Scarcella, 2011; Zimmerman et al. 1992). This means that students who do not fully understand the language of instruction are not able to participate meaningfully in discourse or fully understand the teacher's instruction. Proficiency in academic language of mathematics allows students equal access to mathematical concepts (Boaler, 2002; Rubenstein, 2002). Students who are proficient in mathematical language have access to the teacher's instruction as well as the thinking of classmates. They are also better able to articulate their own understanding or lack of understanding.

Adler (1999) asserts that teachers in her research found that being explicit about mathematical language benefited all pupils in their classes, regardless of the student's language history. Similarly, I found that all of the students in my classroom, from those who struggled to those who were more advanced in math skills began using mathematical language correctly in classroom discourse.

Research on language learning tells us that when students hear and use a language, they become more proficient in that language (Krashen, 1994; Adler, 1999). My findings supported this research. I found that establishing the use of correct mathematical language and terminology in my classroom helped my students begin to use and understand mathematical language. I was cognizant of

maintaining a safe environment for students to try new ideas and language at all times. Instead of correcting errors in language usage, I rephrased the students' words as a clarifying question, using correct mathematical language. When a student told me that they had 'timesed' two numbers, I would repeat, "Oh, you multiplied those two numbers." They began using 'multiplied' instead of 'timesed'. Instead of 'minused', they began to say 'subtracted'.

Words for mathematical operations were simpler to correct than other mathematical terminology. Words that were more specific to mathematics or had different meanings in other contexts were more complicated. Mathematics uses language that can be confusing to some people. There are words that are specific to mathematics and students may have little background knowledge onto which they can connect this vocabulary. Words like integer or denominator are not used in a non-mathematical context. Students do not have familiar contexts to help them learn these words. There are other words in mathematics that are shared with other content and contexts, but do not share meanings, such as similar, power or function. These words may cause more confusion than clarity if the teacher is not careful to ensure students understanding of the use of the word in mathematical contexts. In my classroom, I found that consistently using and reinforcing correct use of the mathematical terminology allowed students to understand and communicate mathematically.

Self-efficacy. Self-efficacy is defined as a student's perception of his/her ability to accomplish tasks and goals as perceived self-efficacy (Bandura, 1997).

When a student has positive self-efficacy, he/she has confidence in her/his ability, understanding, and confidence of success. Many students who lack confidence in mathematics are unwilling to try new concepts or participate in group or classroom discussions. Some of this lack of self-efficacy may appear in group-work as low status students have difficulties participating in tasks or in discussions. (Cohen, 1994).

My question asked whether there might be a relationship between proficiency in mathematical language and self-efficacy. I found a clear trend; as use of mathematical language in discourse grew, student feelings of self-efficacy grew. I do not know whether the growth in self-efficacy was a result of the increase in mathematical language proficiency or whether that growth could be due to classroom norms that value discourse and a positive attitude.

Classroom norms. Research has shown the positive results of establishing sociomathematical norms in the mathematics classroom (Yackel & Cobb, 1996). Yackel and Cobb report that norms do not need to be identical in every classroom, however, norms in a mathematics classroom must be established that involve supporting student discourse. Effective, accessible mathematical discourse requires proficiency in mathematical language (NCTM 2000)

According to the *Principles and Standards for School Mathematics*, (NCTM, 2000) students learn the language more effectively when they hear and use the language in discourse. The research shows that students also learn content more easily and effectively when they are able to verbalize their own thinking and

access the thinking of others. There are strong indications that when students feel that they are able to converse proficiently with others, they are more confident and willing to participate. In the future, I will continue to have students tackle groupworthy tasks together, as well as discussing the more mundane practice problems. I know I need to give much more positive reinforcement for the smallest of steps toward productive discourse and verbalization in mathematics.

Implications. There are many aspects of my research that I would like to investigate again, in smaller, more deliberate pieces. I feel that my students would have benefitted from a more clear understanding of what self-efficacy is before reporting their own feelings. I did not spend time to explain to students; instead I assumed that they would be able to report their feelings without a great deal of instruction. New research could be conducted centering on building self-efficacy through teaching awareness of what self-efficacy is. I wonder whether daily affirmations of a positive attitude toward mathematics and one's ability to perform the tasks may contribute to a growth in self-efficacy.

Following a similar theme, I think about how I could have been more purposeful when talking to students about my research project. I set up the classroom, established norms for my math class, supported the use of mathematical language every day, gave student surveys, and recorded hours of discourse and instruction. I did not implicitly tell students that I was looking to see if there was a relationship between mathematical language and self-efficacy. I felt that if I explained the connections that I felt might be there, students may give

the answers they thought were 'right' instead of being honest. In the end, one of my students reported in an interview that he had rushed through the survey simply to finish it, and had not thought about honesty at all.

Much more time could be spent in any classroom on language and vocabulary (Echevarria, no date). If I were to focus on any aspect of this research study in the future, it would be on academic language and mathematical vocabulary. In the future, I will not assume students know all mathematical terminology from previous years. I will be more deliberate about reviewing these terms and will have students include the words in their notes.

Teachers must use correct academic language in the classroom if they expect their students to be able to use and comprehend that language. Proficiency in the language of any content area is essential to understanding that content. When teachers 'dumb it down' for students, it not only shows a lack of confidence in the students' abilities, but sets students up to struggle in the future, when the content becomes more complex. Why would a teacher instruct students to remember 'magic zeros' instead of teaching the 'powers of 10'? Is this cute language easier for the student or for the teacher? The cute tricks and slang words may work for the short term, but do not help students in discourse later in their academic careers. They will certainly not experience 'magic zeros' when learning scientific notation. Compounding the problem further, other teachers and students will not know what the student refers to when they use incorrect terminology and slang instead of correct language.

Teachers have a profound impact on the students that they work with everyday. Setting students up for future success as learners opens doors for all students, from many backgrounds and cultures. When students learn to communicate mathematically, they are learning more than just the math. They learn to communicate in a meaningful, cooperative manner with others and work toward a common goal. These are skills that will allow the students to become confident, cooperative, problem solving adults.

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APPENDIX A

This is an example of a 4-square vocabulary chart that students use as a format for new vocabulary in their math notebooks.

WORD	DEFINITION IN MY WORDS
DICTIONARY DEFINITION	EXAMPLE/NON-EXAMPLE

APPENDIX B

Math Survey

Name _____

	5	4	3	2	1
	Strongly Agree	Mostly Agree	Agree	Disagree	REALLY Disagree
I am good at math facts					
I am good at solving math problems					
I am good at solving word problems					
I am good at remembering vocabulary					
I am good at following directions					
I am good at explaining my thinking					
I am good at drawing pictures					
I am good at finding patterns					
I am good at finding my mistakes					
I am good at asking questions					

APPENDIX C

Interview Questions

1. Tell me about the last math class you took.

2. How do you feel about math? Do you feel like you are good at math? Are any of your family members good at math?

3. What is easy for you in mathematics? What makes this easy?

4. What is difficult for you in mathematics? Why do you think this is difficult?

5. Have you ever had an experience when you didn't understand what the teacher was saying or what a question was asking?
    a. Was the mathematics vocabulary too difficult?
    b. Did the way the question was worded confuse you?

6. What is your most positive memory of math classes? What made the experience positive?

7. Tell me about a bad (negative) experience you remember having in a math class? What was happening that made the experience negative?

8. How do you use math outside of school? OR How useful is math to you outside of school?

9. How do you see yourself using math when you are grown up?

10. How confident are you that you will be able to do well on the state test (MSP)?

11. What do you think helped you feel more confident in your math ability?

12. What do you think made you feel less confident in your math ability?

13. Do you think that you understand the problems better? Why?

14. Has working on the vocabulary has helped you understand math better? How?

15. Are you able to understand when the teacher, the book, or other students better now that we have been working on using math words during math? How? Why? Explain

16. How has using the math words like product, sum, expression, or evaluate has helped you understand the problems better? Explain