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Increasing Number Sense through Mathematical Discourse in the Primary Classroom

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An Action Research Report

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Abstract

The purpose of this action research is to explore the ways mathematical discourse effects number sense in the primary classroom. A study was done in a first grade classroom with 18 students to determine if increasing mathematical discourse in the classroom through the use of "Number Talks" by Parrish and "5 Practices for Orchestrating Mathematical Discussions" by Smith and Stein, student number sense will increase. The findings suggest that through effective questioning in whole-group and small-group instruction, open- strategy sharing, and quantitative imagery, students' number sense will increase. Students in classrooms with rich mathematical discourse will potentially become more comfortable sharing math strategies and will be more confident in their own mathematical abilities. Sources of data collection include a district written and mandated test to measure number-sense in primary students, a student self-assessment, math unit tests, and teacher field notes. The study was conducted over a six-week time period, it may be more successful if done from the beginning of the school year.

Keywords: mathematical discourse, number talks, quantitative imagery, number sense

It would not be out of the ordinary to walk into a primary classroom and see students talking with one another. Research has shown that classroom discussion is integral for students to create a deep understanding of a topic. These discussions can have a great impact on student achievement. While discourse in the classroom may be nothing new, it has often been overlooked in the area of mathematics. Mathematical discourse involves a whole-class discussion where individuals or groups discuss mathematics in such a way which reveals their understanding about mathematical concepts. Through the discourse primary students gain a deeper understanding of mathematical concepts and build a greater number sense foundation.

Low number sense in first grade students is something that a Minnesota school district has deemed as an area of concern due to unsatisfactory results on a test designed to measure number sense. In the 2013-2014 school year, the district started testing kindergarten and first grade students on number sense using a district-developed test called the Concepts of Math (CoM). In the 2013-2014 school year, 61% (64 of 105) of first grade students were proficient in the CoM. In the 2014-2015 school year, 64.7% (77 of 119) of students reached proficiency. After reflecting upon my own teaching practices of these students, I realized that these students have been exposed to a small amount of open-strategy sharing, but it had not previously been accompanied by strategic questioning or discourse. I began to explore in what ways would increasing mathematical discourse in the classroom effect number sense in first grade students.

The literature reviewed explores different ways to increase mathematical discourse to improve student learning in a primary classroom. Current research by Parrish (2014) and Smith and Stein (2011), indicates that increasing mathematical discourse in the classroom through the use of both whole group and small group questioning with the inclusion of open-strategy sharing will increase number sense in students. Primary students will highly benefit from quantitative imagery. These students should be exposed to quantitative imagery during the discussions. Throughout this discourse, students will learn to compute numbers flexibly by learning to compose and decompose numbers and using known and derived facts to solve problems.

Review of Literature

Mathematical discourse has long been shown to improve student success in mathematics, but it can be difficult for teachers without proper training or mentoring (Bennett, 2010). To many teachers, increasing discourse during whole-group instruction can seem time-consuming and overwhelming. A recent study examined two teachers who worked with a mentor to improve their own mathematical discourse (Bennett, 2010). Both teachers reported that they “included more students in discussions, asked more questions that probed for understanding, and reduced the amount of time spent delivering instruction” (2010, p.82). According to Parrish (2014), learning how to teach discourse by using discourse helps the prospective teacher learn effective teaching strategies and how students will respond. “Because a primary goal of number talks is to help students make sense of mathematics by building on mathematical relationships, our role must shift from being the sole authority in imparting information and confirming correct answers to assuming the interrelated roles of facilitator ,questioner, listener, and learner” (2014, p. 203). Discourse oriented instruction should focus heavily on questioning. While multiple types of questions are necessary and encouraged, Piccolo, Harbaugh, Carter, Capraro, Capraro (2008), suggested that *Why* questions led to greater understanding than closed-ended questions. Van de Walle (2013) supported this idea, “Both procedural and conceptual knowledge are important, and questions must target both” (p. 45). Teachers who are purposeful in their implementation of discourse will be able to target conceptual knowledge by altering how they phrase questioning. When teachers ask high-level questions, they enable divergent student responses. Divergent responses represent different points of view without necessarily being incorrect, for example, answers that present alternative approaches to solving a problem" (Henning, McKeny, and Balong, 2012, p. 458). Asking students to consider why an answer is efficient or reasonable allows students to consider the multiple ways in arriving at a solution.

While questioning is important in a whole-group format, it is equally important in a small-group setting. In, "Small-Group Discourse: Establishing a Communication-Rich Classroom" Quebec (2013), explore teachers' strategies for encouraging and enhancing student-to-student communications (p.96). The results of the study include descriptions of common communication issues. Some of the common communication issues include, students not being able to communicate without a dominant student or teacher, one or two students not participating in the discussion and students blindly accepting the answers of others (2013, p. 86). The study includes intervention strategies to encourage student discourse in a small group setting. Some interventions suggested by Quebec include: "Ask students to specifically state their questions, redirect the questions to the group, and refer students to other resources (notes definitions and hints)" (p. 97). However, students may feel hesitant to express their ideas or make conjectures publicly, even in small groups, if they do not feel supported (Parrish, 2011, p.201).

One key way to support mathematical discourse and questioning in the classroom is through open-strategy sharing. In addition to *why* questions, the teacher asks *how* questions. For example, "How did you think about the problem?" One of the most important questions that a teacher can ask during open-strategy sharing is "Who did it a different way?" Teachers should be purposeful in selecting problems; they should choose problems that can be solved multiple ways. Drake et al. (2015) explain that while teachers are often expected to use a particular mathematics curriculum series, the questions that a teacher asks should be able to "build on and connect to children's *multiple mathematical knowledge bases* (MMKB). Children's MMKB include children's mathematical thinking and children's home-and community-based mathematical funds of knowledge" (p.348). This type of mathematical thinking is supported by open-strategy sharing because it includes multiple strategies to solve problems as well as clears up common confusions or misconceptions about math.

In Number Talks (2014), Parrish suggests using questions to bring out misconceptions, "We must remember that wrong answers are often rooted in misconceptions, and unless these ideas are allowed to be brought to the forefront, we cannot help students confront their thinking" (p.38). Encouraging multiple solutions and strategies that connect to a student's MMKB can increase student capacity to solve problems. The practice of justifying their own solutions and the ability to compare and contrast solutions to math problems will deepen mathematical understanding (Drake et al., 2015).

While open-strategy sharing is closely related to questioning, one of the key differences is the student's ability to explain their own mathematical thinking. As students become more comfortable with sharing, they will rely less on the teacher to lead the questioning, and will move toward being able to question and learn from each other. In a study done by Hufferd-Ackles, Funson, & Sherin (2004), a class was studied for a year as they moved through the stages of number talks and open-strategy sharing. "As students learned to explain their own mathematical thinking more fully and fluidly, they made significant contributions that could be questioned or built on by other students and assessed by the teacher" (p. 97). Smith and Stein (2011) suggest that they key to mathematical discussions, and open-strategy sharing is maintaining the right balance between accountability and student authorship. They maintain that too much focus on accountability can encourage an increased reliance on teacher direction. Conversely, too much focus on student authorship can quickly get out of control.

An additional key component of mathematical discourse and open-strategy sharing in the primary classroom is quantitative imagery and subitizing. Newbury, Wooldridge, Peet, & Bertelsen (2015) argue that one of the most important determiners of future math success is number sense. “These numerical competencies are the basic building blocks of all future mathematics and include skills such as number recognition, counting, quantity discrimination (magnitude), basic number combinations, number patterns, early addition and subtraction, and development of a mental number line” (p.3). Students who can mentally visualize numbers without having to count will have a stronger math sense. Moving beyond physical interactions with materials is a significant step toward building number sense. Thomas and Tabor (2012), spoke of this journey being difficult for some students. However, if teachers can help students "see" math with their "mind's eye" via the construction of quantitative mental imagery, the student will build a stronger number sense for future math problem solving. Thomas and Tabor assert that "The key to moving away from dependence on materials lies in the construction of quantitative mental imagery" (p.177). Exposure to imagery such as domino patterns, ten frames, and number lines will help students create a frame for their quantitative mental imagery and will help them bridge the gap between subitizing and direct counting/modeling. If students can develop pattern recognition and capabilities such as composing and decomposing numbers, they will build valuable number sense components.

The type and level of questioning in both whole-group and small-group instruction will impact number sense. When teachers learn to increase mathematical discourse in the classroom, the outcome is greater participation in mathematical discussion and an increase in mathematical thinking. Questions should be designed to increase the level of automaticity in a classroom so that students begin questioning one another, themselves, the teacher, and the mathematics presented. One way that this can be achieved is through number talks, where students are given a math problem to solve mentally, followed by open-strategy sharing. This approach will not only teach students new and multiple ways to solve problems but will also help to clear up common misconceptions.

Being able to question others and provide rationale for their own thinking, demonstrates a level of understanding of mathematics. Firmender (2014) states, "As a whole, previous and current results suggest that engaging students in verbal communication may be positively related to students' mathematics achievement (p.231). In the primary classroom, the use of subitizing and quantitative imagery are essential for building early number sense skills. These should be explicitly taught and exposed to students regularly as part of the number talks, discussions, and open-strategy sharing sessions. "Number Talks" by Sherry Parrish and "The Five Practices for Orchestrating Productive Mathematics Discussions" by Margaret Smith and Mary Kay Stein may be helpful guides for structuring discourse in a primary classroom setting.

Methodology

The study was conducted in a regular education first grade classroom with 18 students. Several artifacts were gathered before, during, and after the study. Students were assessed on the district Concepts of Math (CoM) test. This test was designed to assess number sense in primary students. Baseline data was gathered at the beginning of the school year and the CoM is administered in a one-on-one setting per trimester. This is a standardized and mandated test. It is comprehensive and covers nine different strands of number sense. Student mathematical proficiency was also measured with the math unit tests. Formative and summative tests for one unit of math were given. The math formative and summative assessments were written by the school district. Field notes/observational records were gathered during number talks and math class on the following: student participation, automaticity in solving problems, ability to solve problems using known and derived facts, willingness to open-strategy share. A self assessment (see appendix A) was also given to all students before and after the study to judge their attitudes and willingness toward math and solving math problems.

At the beginning of the study students were explicitly taught the expectations of conduct for a number talk using the Perrish format. Students sat in their designated spots on the rug and waited for the teacher to pose a question. When the student mentally solved the problem posed, they put a thumb up at chest level. If students finished early they were instructed to try to think of another way to solve the problem. When they thought of another way they would hold up a finger or fingers to indicate how many different ways they had solved the problem. This allowed the teacher to give ample wait- time to students who may solve the problem slower and it kept quick thinking students engaged during that time. It is important that the teacher sets up the expectation that all answers are important and valued. Students would therefore understand that just as much is learned from incorrect answers as correct answers. Ideally, a positive classroom climate will have already been set. Students were also taught non-verbal signals to give to one another such as: “me too”, “I agree”, “I need clarification”, and “making a connection.”

During the study, number talks were done daily during “morning meeting.” The teacher posed a daily math problem to be solved mentally. The questions posed reflected the teacher’s learning targets for the class. The learning target took into consideration where students were in terms of their overall learning goal. For the study, the learning targets were: recognizing multiples of ten, subitizing ten frames up to 60, recognizing number patterns, composing numbers, and combinations to ten. The number talks generally lasted between five to ten minutes.

After the question was posed and sufficient wait-time was given, several students shared their answers. The teacher recorded all answers on the board, never giving feedback as to which answer was right. A few students were then asked to share their thinking about how they got the answer, occasionally students were asked to “turn and talk” and share with the person(s) sitting near them. The teacher recorded the thinking (when applicable). As students shared out their own thinking, other members of the class would give the previously agreed upon non-verbal signals. The class then determined the correct answer for the problem. The teacher was the facilitator in the discussion (as opposed to the leader) and asked questions such as: “Who would like to share their thinking?”, “Who did it another way?”, “Who solved it the same way?”, “How did you figure that out?”, and “What is the first thing your eyes saw /your brain did?” These math discussions happened daily throughout the study.

Another part of the study included a math “Problem of the Day” to be solved in student notebooks. This section of the study employed the techniques of “The 5 Practices for Orchestrating Productive Mathematical Discussions” by Margaret Smith and Mary Kay Stein. With these problems, students were encouraged to write about math, and then share their problem solving strategies and solutions.

The first of the “5 Practices” is *anticipating* what students will do, what strategies they will use in solving problems. Students were given both addition and subtraction story problems. The problems were read aloud, and then passed out to students at the beginning of “intervention time”. Students solved the mathematical problem, explained their thinking in their notebook and left the notebook on their desk. To start, the problems were more simple (addition and subtraction within finger range) and grew in complexity (addition and subtraction to 20) throughout the study. Based on previous knowledge of students, as well as a history of teaching first grade and the knowledge of how first grade students progress in their problem solving skills, the teacher anticipated that there would be many students who were still using direct modeling strategies and many students that were counting on by ones. It was also anticipated that there would be a small number of students that were using non-counting strategies.

The second practice is "*monitoring*." As students worked through the problems, the teacher monitored how they approached the problem solving and how they explained their work or strategies. Field notes were gathered on how students solved the first problem and how they progressed to more complex strategies. For the first problem, many students had trouble explaining their thinking in writing.

After monitoring the students, the teacher *selected* (practice three) students whose strategies were worth sharing. To start, the teacher selected a full range of strategies based upon how clearly a student showed their thinking. Practice four involved *sequencing* student presentations for maximizing their potential to increase student learning. To start, the teacher started with the most basic strategies (direct modeling) moving up through the most complex (non-counting). Students gathered on the rug with their notebooks (if a student used manipulatives or other materials the notebooks were left on their desk). The students that the teacher pre-selected were asked to bring their notebook to the document camera, project their work, and share their problem solving strategies with the class in the roll of the teacher. Students who used manipulatives or materials carefully carried their notebooks to the document camera and explained how they used the materials to solve the problem. As students shared their problem solving strategies, members of the class used their non-verbal signals to show if they also solved the problem the same way.

Practice five consisted of *connecting* the strategies and ideas in a way that helps students understand the mathematics learned. At the launch of the “problem of the day” routine, class posters were made to highlight different problem solving strategies. These posters allowed students to see how their own mathematical thinking could be represented in writing. As students came up with new strategies, new posters were made to explain thinking. The posters, or anchor charts were then hung in the classroom and used as a problem-solving menu.

The same principles of mathematical discourse were also used within small-group “guided math” sessions. Students were encouraged to share their thinking and explained their problem solving strategies with both the teacher and other members of the group. The teacher used questioning to extract mathematical misconceptions. Often times in these small group sessions, students were comfortable talking about their mistakes and learning the skills to self-correct. Students were also more apt to question a peer’s thinking in a small-group setting.

As students needs and abilities change, the level of questioning and discourse changed to meet the needs of the group, as well as the needs of the individuals. The questions and student responses were purposeful and related to group and individual goals.

After the study, the teacher administered the CoM to all 18 students in a one-on-one setting. Students also took one district-written unit math summative test where data from the “uses computational strategies” section of the test was compared to the same strand of the formative assessment. Field notes/observational records were gathered during the duration of the study, reviewed weekly and analyzed after the study. The teacher also looked at each individual student’s “math notebook” to see the progression of problem-solving and computational strategies. The student self assessment (see appendix A) was also given to all after the study and compared to the same assessment that they took before the study.

The teacher compared and analyzed the data to gain perspective of student growth in the area of number sense. The teacher used the data to inform future instruction in terms of methods of teaching number sense to first grade students. The teacher also used the data to gain insight on whether increasing mathematical discourse, utilizing quantitative imagery, and open strategy sharing has an impact on increasing number sense in first grade students.

Analysis of Data

The first artifact analyzed was the student self-assessment. The data of the self-assessment was somewhat inconclusive. While some students reported improvements in almost every area, other students reported an overall decrease in their feelings about their own math proficiency and attitude. When the self assessment was given, 5 out of 18 students answered both the baseline assessment and final assessment with a score of 5 in every category. The age of the students may have been a factor in the assessment. Some first grade students have not yet developed the ability to accurately self-assess.

While there was not a pattern of improvement for each student, all categories showed overall improvement when looked at as a whole.

Table 1. Individual student scores for the attitude/feeling self assessment (appendix A).

	I can solve math problems			I can solve math problems without counting on my fingers			I can explain how I solve math problems			I like to share my math strategies with my class			I am good at math		
Student	B	F	C	B	F	C	B	F	C	B	F	C	B	F	C
a	4	5	**+1**	5	5	**0**	2	3	**+1**	2	2	**0**	5	5	**0**
b	4	5	**+1**	5	5	**0**	3	5	**+2**	1	5	**+4**	4	5	**+1**
c	3	5	**+2**	1	5	**+4**	1	3	**+2**	5	2	**-3**	4	2	**-2**
d	5	3	**-2**	5	5	**0**	5	2	**-3**	5	5	**0**	5	4	**-1**
e	3	3	**0**	4	3	**-1**	4	3	**-1**	5	3	**-2**	3	3	**0**
f	4	5	**+1**	5	5	**0**	2	3	**+1**	3	5	**+2**	5	5	**0**
g	5	5	**0**	5	5	**0**	5	5	**0**	5	5	**0**	5	5	**0**
h	5	5	**0**	5	5	**0**	5	5	**0**	5	5	**0**	5	5	**0**
i	4	4	**0**	5	4	**-1**	1	5	**+4**	5	5	**0**	5	5	**0**
j	3	5	**+2**	2	5	**+3**	5	5	**0**	5	5	**0**	4	5	**+1**
k	3	5	**+2**	1	4	**+3**	3	3	**0**	2	5	**+3**	5	5	**0**
l	5	5	**0**	5	5	**0**	5	5	**0**	5	5	**0**	5	5	**0**
m	5	5	**0**	5	5	**0**	5	5	**0**	5	5	**0**	5	5	**0**
n	5	5	**0**	4	5	**+1**	3	5	**+2**	3	5	**+2**	5	5	**0**
o	3	5	**+2**	3	5	**+2**	4	5	**+1**	4	3	**-1**	5	5	**0**
p	5	5	**0**	4	5	**+1**	3	5	**+2**	4	5	**+1**	2	5	**+3**
q	3	3	**0**	4	5	**+1**	5	5	**0**	5	5	**0**	4	5	**+1**
r	5	5	**0**	5	5	**0**	5	5	**0**	5	5	**0**	5	5	**0**
			+9			**+13**			**+11**			**+6**			**+3**

Key: B=Baseline Assessment, F=Final Assessment, C=Change

1= Strongly Disagree, 2= Disagree, 3=Neutral, 4=Agree, 5=Strongly Agree

Table 1 displays individual student results of the baseline assessment and the final assessment as well as the change between them. Figure 1 depicts the overall change in score for each of the questions asked.

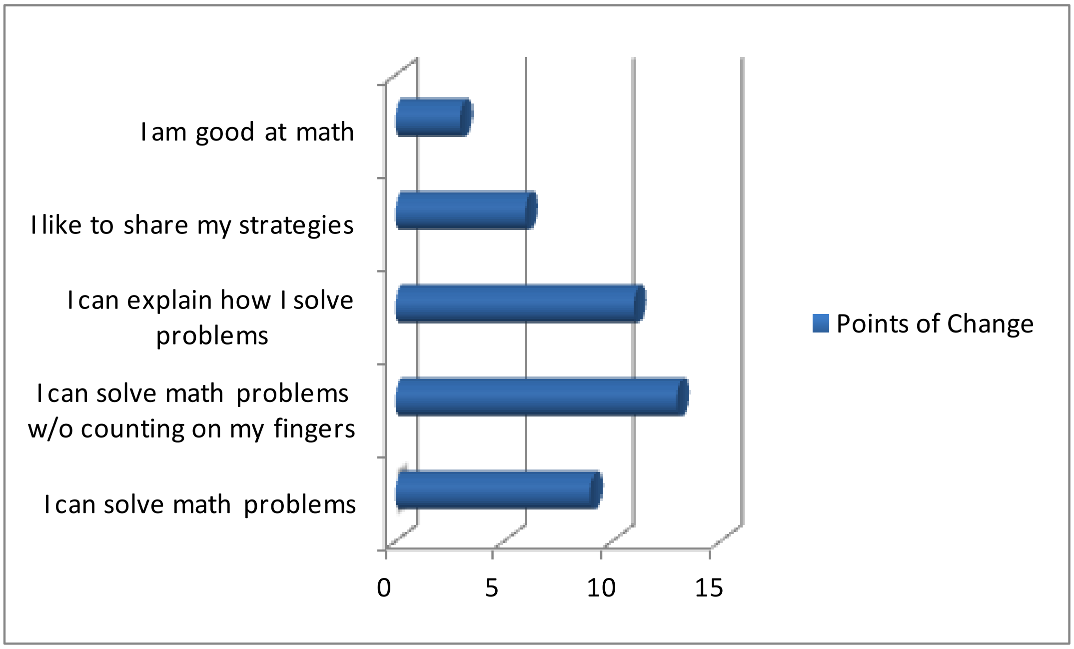

Figure 1. Overall improvement for each question of the self assessment.

Students who reported a decrease in multiple areas were also interviewed by the teacher about their response. Student “d” explained the decrease in scores with a better understanding about math and mathematical problem solving strategies as well as a better understanding of self-reflection. The student explained: “Well, when I first took the test I didn’t really understand the questions. I didn’t know about math problem solving but now I know that there are lots of different ways to solve a problem. I know I am getting better at math, I just understand the questions better now.” Student “e” responded: “Yeah, I didn’t really know what you were asking before.” Several other students were interviewed by the teacher about their responses. Based upon the student responses, it could be determined that students have gained a better understanding of the progression of mathematical problem solving. Many students are now working towards solving problems by using a non-counting strategy. Before the study, these students did not know what a non-counting strategy was; therefore, they could not have the understanding about what they were working toward.

The area of the assessment that had the highest rate of change was “I can explain how I solve math problems.” In this area, 9 out of 18 students reported improvement. Only one student reported a decrease, but could not explain why. It could be deduced that throughout the daily practice of explaining problem solving and hearing peers solve problems, students became more confident in their own ability to render such explanations.

Another area with a large range of improvement was “I can solve math problems without counting on my fingers.” At the beginning of the study, many students were solving mathematical problems using direct-modeling with their fingers. Some students reported no change on the assessment but clarified that they no longer use fingers to direct model, but still use them to count on or back. The progression from direct modeling to counting on is still an improvement in skills, but the improvement is not represented in the data.

The second data source that was analyzed was the unit math test. The unit tests are written by the school district curriculum writing team. They are aligned with the first grade MN state standards as well as the district standards. The tests are the intellectual property of the school district. The section of the test that was most applicable to the study was “Uses Computational Strategies to Solve Problems.” On the formative assessment, 12 out of 18 students were proficient in this standard. On a previous unit test 12 out of 18 students were proficient in this standard. After the study 17 of 18 students were proficient. Figure 2 illustrates student proficiency of past tests (formative and past tests) as well as the unit test given after completion of the study (summative unit tests).

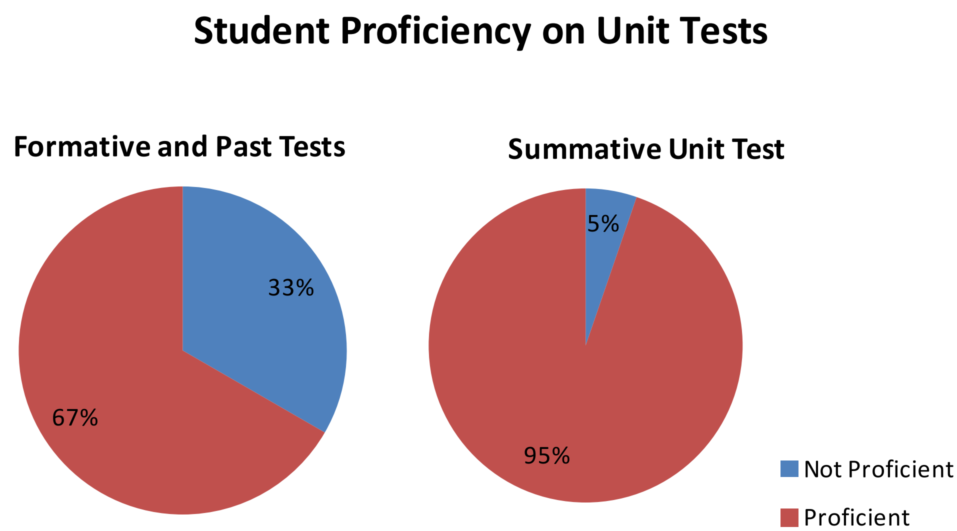

Figure 2. *Comparison of student proficiency on formative and past tests (before the intervention) and the unit summative test (after the intervention).*

Tests from the same unit from previous years are consistent with the first chart in Figure 2. Expected proficiency in the standard is anywhere from 60-80%. The unit test given after the study showed abnormal proficiency for the standard. It is likely that students being more aware of problem solving strategies, in addition to practicing problem solving on a daily basis led to the increase in student proficiency.

The third artifact that was analyzed was teacher field notes. The teacher noticed trends in student participation. Since the number talks took place during the “morning meeting” portion of the day, many of the previous “calendar math” routines were replaced. Previous calendar routines included: adding a penny, counting coins and exchanging when necessary, adding a dot to a ten-frame, subitizing the ten-frame, adding a “ones cube”, exchanging and counting when applicable, adding a tally mark, adding a stick, bundling when applicable, some type of choral counting exercise, etc. Students were generally engaged in this routine at the beginning of the school year, however, after doing this daily for a few months, many students lost interest and became disengaged. The higher achieving students were not challenged during this daily routine. They were able to easily see the number patterns and predict the next steps. At around the same time, the numbers got too big for the lower achieving students to comprehend. Since the routine was generally the same every day, many students grew bored with it. The Number Talk routine had a much higher level of student engagement. The higher achieving students tried to figure out multiple ways to solve each problem, the lower achieving students were granted ample wait-time to solve problems as well. Since the type of questioning was diverse, student engagement was much higher. Students were still exposed to the calendar for dates, days of the week, and recording special occasions; the “helper of the day” kept the daily count going for all of the other pieces.

Students also became more willing to open-strategy share; they were very eager to explain to the class how they solved or “saw” a problem. In the past, students were often hesitant to solve a problem unless they were confident that they had the correct answer. During the Number Talks routine students became more willing to question one another (respectfully) and to justify their own thinking when questioned. They were also willing to take risks because they understood that a wrong answer was not a bad thing.

The teacher also analyzed student thinking and sharing of “problem of the day” strategies in their math notebook. Throughout the course of the study the selection process of how students shared thinking evolved. Sometimes the discussion was specific to problem solving strategies, other times the discussion was about which strategies were more efficient. After the menu of choices was clearly established, and students had a clear understanding of different ways to solve problems, they were encouraged to try solving the problem a different way. Some students went from a more complex strategy to a more basic strategy and they shared that the basic strategy took longer and was often times less accurate. As the numbers in the problems got bigger, the class noticed that it was easy to be off by one number when counting by ones. Students also made observations that they “ran out of fingers” when numbers reached above ten. Conversely, students who used a basic strategy were often pushed to try a more complex strategy. Many of them were pleased to find the more complex strategies to be “easier” (less time consuming, did not have to go get materials). Sometimes students would still use direct modeling but would solve at the pictorial level as opposed to the concrete.

Figure 3 shows the progression from the most basic problem solving strategy (direct modeling) and moves up to the most complex (non-counting strategies). Many students moved through these quickly once they began to try new ways of solving problems.

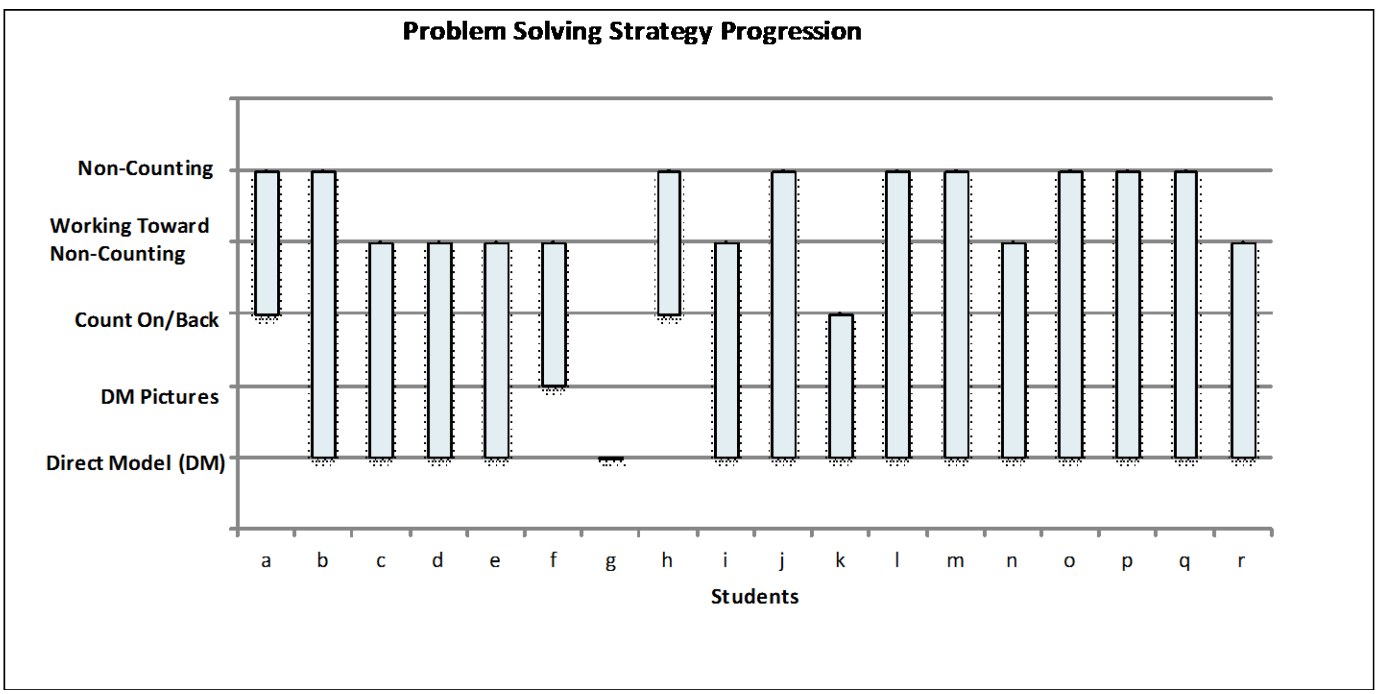

Figure 3. *Individual students’ problem solving progression. Each line represents individual student progression.*

With the exception of one student who remained at the direct modeling level, all students progressed in terms of problem solving strategies. While some students have not yet mastered a non-counting strategy approach, many students were working towards it. These students can use non-counting strategies at a basic level (doubles facts to 10, near doubles, and parts of 10) they were not yet able to use the strategy for more complex computation.

The last piece of data analyzed was the Concepts of Math (CoM) test. This test was written by the district to measure number sense in primary students. The test was given to students at the beginning of the year (baseline), at the end of trimester 1 (before the study), and at the end of trimester 2 (after the study). The test is given in a one-on-one setting and students must answer all questions orally. Figure 4 shows overall CoM proficiency for the class involved in the study.

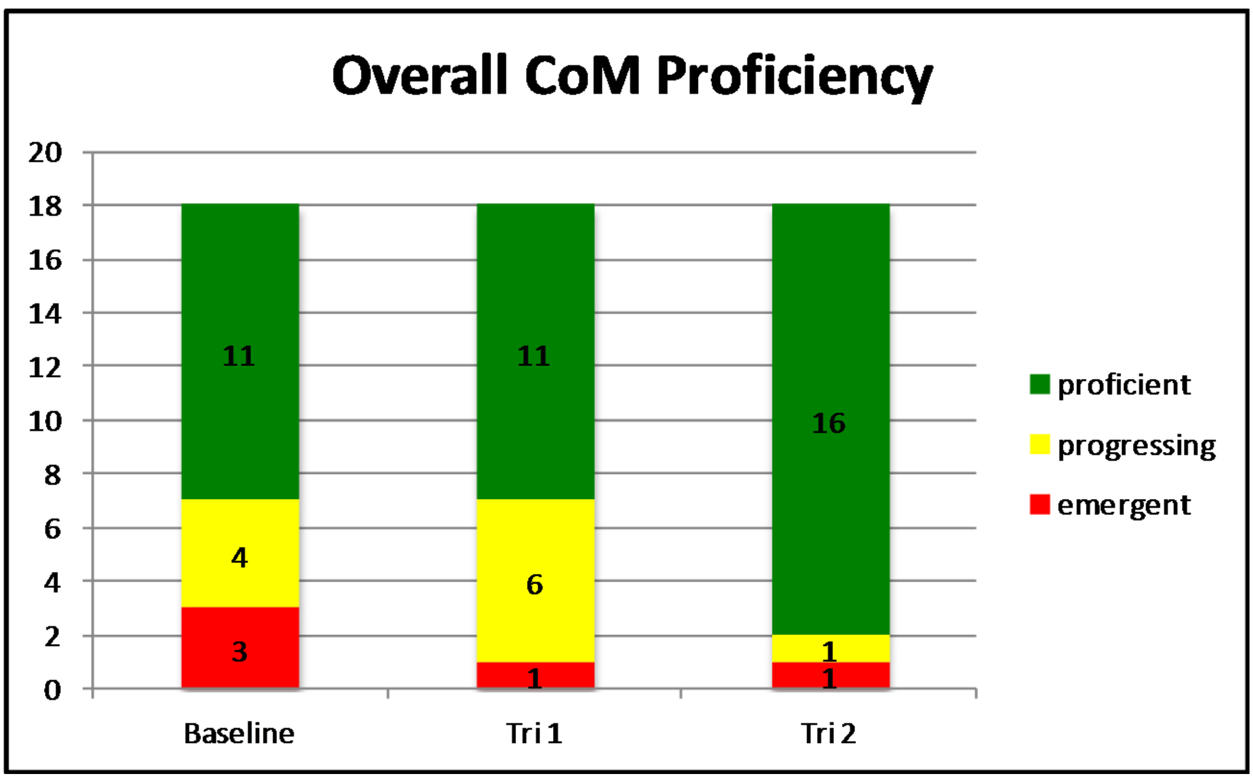

Figure 4. Overall proficiency on Concepts of Math test. Each bar shows how many students (out of 18) were proficient, progressing, and emergent. Results are displayed for baseline (beginning of year), trimester 1 (before the intervention) and trimester 2 (after the intervention).

Test results indicate an overall higher proficiency on the CoM test. Between baseline data and trimester 1, there was an increase of progressing students and a decrease of emergent students but the number of proficient students remained the same. Between trimester 1 and trimester 2 there was an increase of 5 students in the proficient category.

Looking at CoM trends over time, the growth between trimester 1 and trimester 2 is above average. The school district expects nine points of overall proficiency growth between trimester 1 and trimester 2. Students who were exposed to regular mathematical discourse had above average growth on the Concepts of Math test. The students involved had both higher than expected, and higher than previous class averages between these two trimesters. Figure 5 details this.

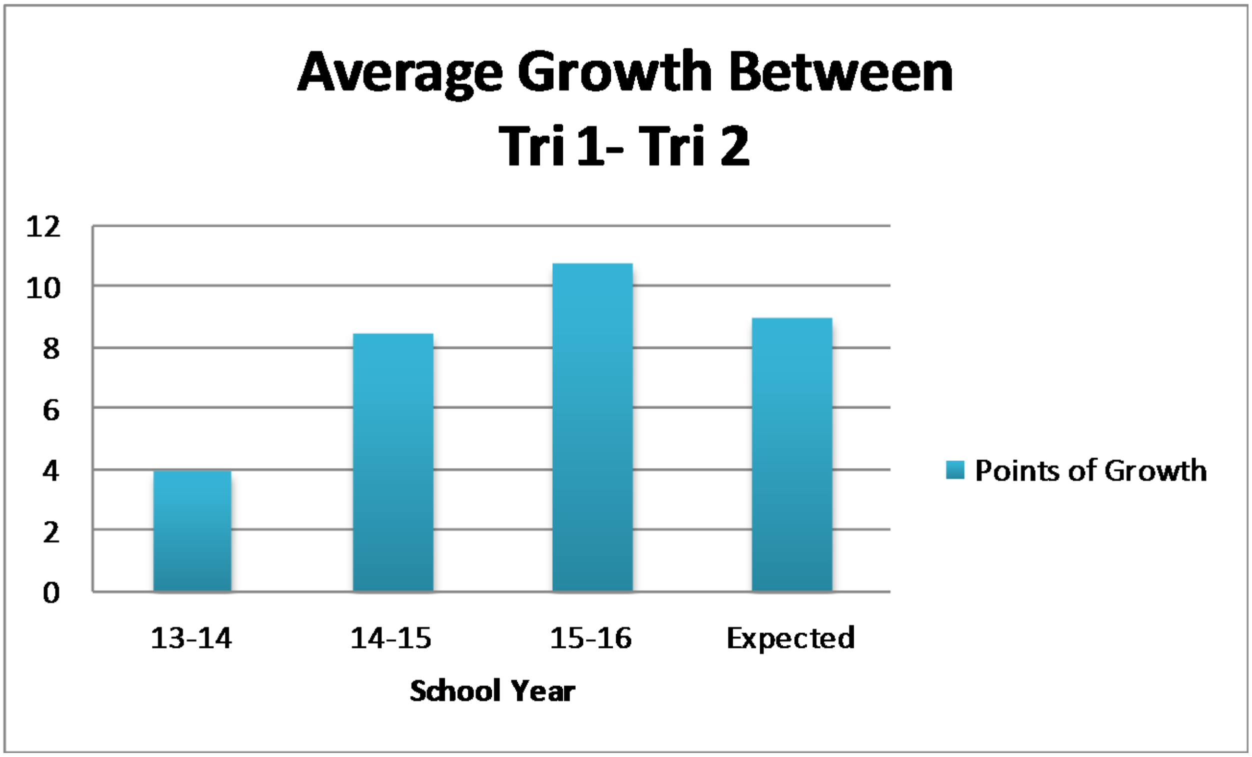

Figure 5. *Average growth between trimester 1 and 2 for the past 2 school years as well as current growth and growth expected by the district.*

The CoM test results were broken down even further. The CoM involves nine different strands of mathematical proficiency: Forward Counting, 1 More/10 More, Numeral Identification and Order, Backward Counting, 1 Less/10 Less, Compose and Decompose Numbers, Addition, Subtraction, and Skip Counting. Figure 6 indicates student proficiency in each strand of the CoM at the end of trimester 1 (before the study) and Figure 7 shows the same data at the end of trimester 2 (after the study).

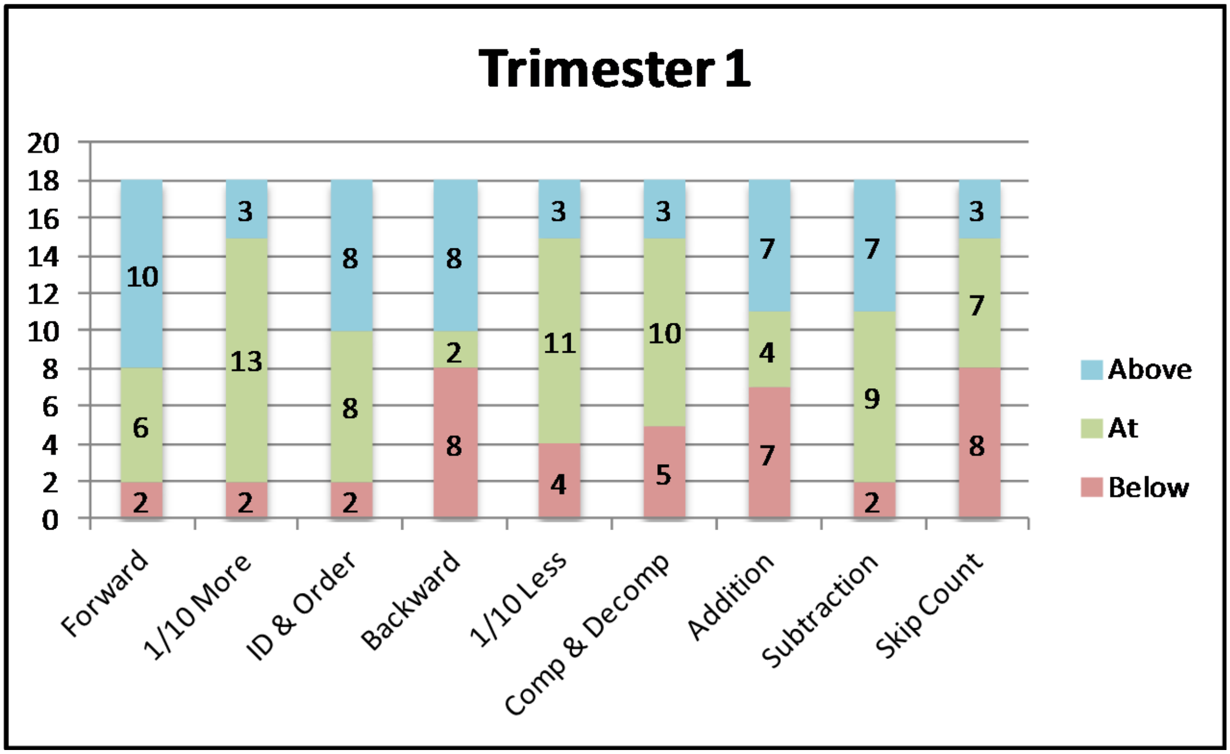

Figure 6. *Trimester 1 data for each strand of the CoM. This figure depicts how many students (out of 18) were below, at, and above grade level before the intervention.*

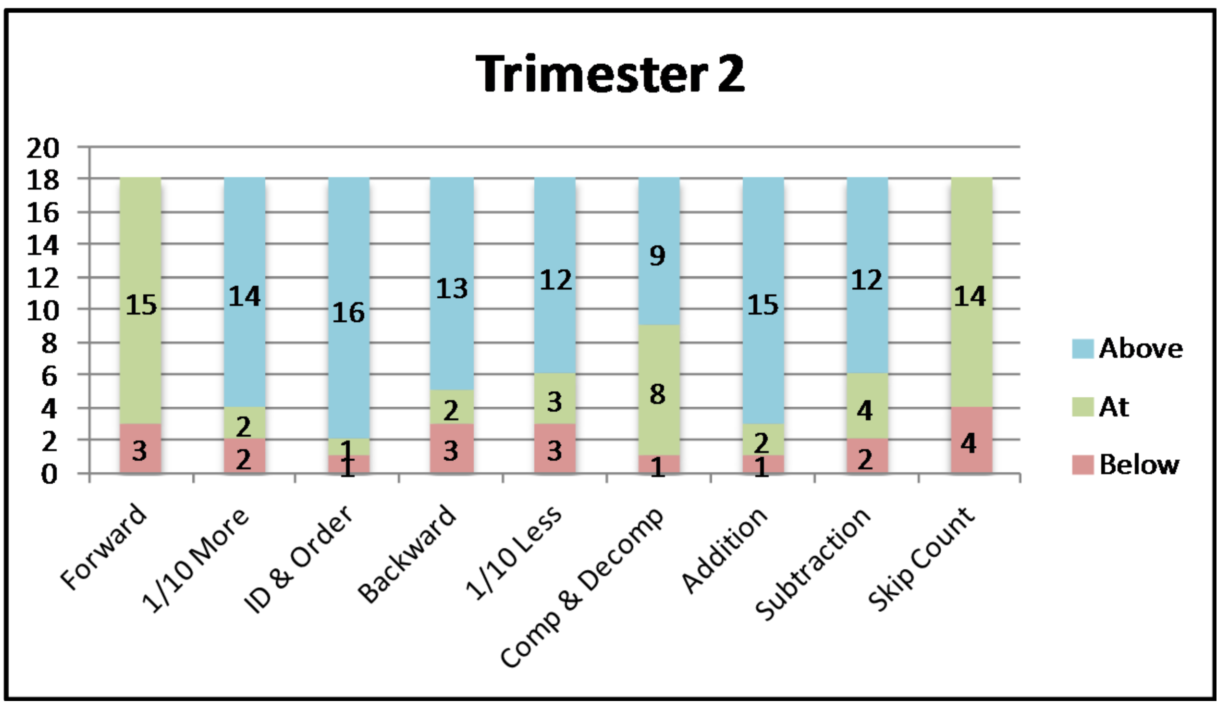

Figure 7. Trimester 2 data (after the intervention) for each strand of the CoM. This figure depicts how many students (out of 18) were below, at, and above grade level. It is important to note that it is not possible for a student to be above grade level in forward counting or skip counting in trimester 2.

The two figures show a decrease in students below grade level in 6 out of 9 strands. In some strands, specifically Forward Counting and Skip Counting, it is not possible to receive an "Above Grade Level" score in Trimester 2. Looking at the strands where it was possible to receive an "above" score, 100% saw an increase in students performing above grade level expectations. When students create knowledge socially through discourse oriented classrooms, they are able to make sense of math instead of ritualizing it, therefore creating stronger number sense. When students consistently write about mathematics, it allows them to express an improved understanding of the concepts that they have learned. Student success can be measured in both an increase in student test scores, as well as an improved student attitude in the area mathematics. There are many things that can be done in the classroom to increase the level of discourse.

Action Plan

After reviewing all of the artifacts it is evident that increasing mathematical discourse has a positive impact on student achievement and learning. Implementing a discourse oriented classroom at the beginning of the school year would be beneficial. Building an atmosphere of trust is crucial for a facilitator of such discourse. Students build self-efficacy when they knew they are respected. In a discourse oriented classroom, students create their own learning; this will develop automaticity as they became confident in being the authority of their learning as opposed to the recipient. Some key resources to increase mathematical discourse in primary classrooms are "Number Talks" by Sherry Parrish (2014) and "The Five Practices for Orchestrating Productive Mathematics Discussions" by Margaret Smith and Mary Kay Stein (2011).

After examining the data, the following improvements could be made to the intervention for further mathematic success:

- The discourse should start at the beginning of the school year and be carried throughout the year as a normal classroom routine.
- All first grade students should be exposed to a discourse oriented classroom, as opposed to just one classroom.
- Teachers will need training to properly set-up and execute successful discourse.

Whole-group number talks at the primary level should include quantitative imagery to build number sense. Parrish, Smith, and Stein all promote the importance of open-strategy sharing for students. When students have the opportunity to show or explain their mathematical thinking, it reveals both understandings and misconceptions. Teachers must become skilled in terms of questioning. The focus will need to be shifted from “what is the correct answer”, toward “how did you solve the problem”. This level of questioning should be happening in both whole-group and small group mathematical settings.

One drawback of the study was that it was only applied to one classroom. In the future, if other classroom teachers implemented a discourse oriented classroom, the results would likely be extrapolated to include more student success. In order to successfully increase mathematical understanding for students, the support for teachers must be implemented. “The Development of an Instrument to Measure Preservice Teachers’ Attitude about Discourse in the Mathematics Classroom”, by, Tutita M. Casa, Jean McGivney-Burelle and Thomas C. DeFranco (2007), studies the attitude of many teachers regarding mathematics and discourse. Numerous teachers in the study held a pessimistic view of discourse and mathematics in general, based on personal experiences and lack of experience in a discourse reformed classroom.

Training for teachers on implementation of discourse will be important if they do not have the frame-work of experience (Casa, et al., 2007). Professional development regarding discourse practices needs to be continuous and well supported. Facilitators should be given opportunities to share ideas, create lessons and reflect upon how to best get students of mathematics talking about their learning. Teachers should be provided with opportunities to further their knowledge on implementation of mathematic discourse and specific mathematic vocabulary in their classrooms. This training does not need to be extensive, but is a vital aspect of the promotion of communication of mathematical thinking.

The way the teacher sets up classroom expectations is paramount for successful number talks. In the article, “Creating Cultures of Participation to Promote Mathematical Discourse” by, Cory A. Bennett (2014), a common theme is found in classrooms that have successfully implemented mathematical discourse, “Classrooms were inclusive, all individuals’ comments and ideas were valued and respected, contributions from all students were expected, all students engaged in the open sharing of ideas at some time, and the students collectively shaped understandings with guidance from the teacher as needed” (p. 21). Norms need to be established and referred to often, not just at the beginning of the year. Expectations of participation are essential and imperative to success. Students should come to class with the understanding that they will be expected to contribute and take an active role in their learning (Bennet, 2014). Teachers will need to make this an expectation as they set up routines.

Beyond conversing about math, a discourse oriented classroom should include writing about math. Students would benefit by showing their understanding of a mathematical concept, and sharing the writing with their peers. Smith and Stein's "5 Practices" work well as a framework. "Writing allows students to better express their understanding of the concepts" (Cross, 2009, p. 920). When students engage in argumentation and written discourse they tend to express their ideas more concretely and provide evidence when pressed to explain their thinking. Their writing and oral discourse becomes more condensed while generating ways to explain their understanding (Cross, 2009). Students critique each other's writing and validate or question the thinking of others when involved in active discourse. Almost all students involved in the study (17/18) showed an increase in the complexity of the strategies used, as well as the ability to write about the strategies. The ability to explain mathematical thinking by writing will also aid students on paper/pencil tests.

When students create knowledge socially through discourse oriented classrooms, they are able to make sense of math instead of ritualizing it, therefore creating stronger number sense. When students consistently write about mathematics, it allows them to express an improved understanding of the concepts that they have learned.

One concern regarding the implementation of a discourse-orientated classroom is ensuring that discourse is done for analytic purposes and not solely for the social aspect. Students may not always connect the purpose of discourse to the content focus. While the students in this particular study were highly engaged in the discourse, it would be important to note if the same engagement continued over a longer period of time. Williams and Baxter (1996) state, "In some cases, the discourse became for students an end in itself. In others, it became another superfluous requirement (p.36). While the study was specific to middle-school, the same struggle could be applicable in a primary setting.

While the increase in number sense for primary students is a benefit, there may also be additional benefits not considered. Students will gain a better understanding of the progression of mathematical problem solving, therefore having a goal or desire to achieve higher levels of problem solving skills. It is also likely that with the increase of understanding of mathematical concepts, students will have higher confidence in their own mathematical abilities.

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Appendix A

Name____________________________________

I can solve math problems.	 Strongly Disagree / Disagree / Neutral / Agree / Strongly Agree
I can solve math problems without using materials.	 Strongly Disagree / Disagree / Neutral / Agree / Strongly Agree
I can explain how I solve math problems.	 Strongly Disagree / Disagree / Neutral / Agree / Strongly Agree
I like to share my math strategies with my class.	 Strongly Disagree / Disagree / Neutral / Agree / Strongly Agree
I am good at math.	 Strongly Disagree / Disagree / Neutral / Agree / Strongly Agree