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The Impact of Regular Number Talks on Mental Math Computation Abilities

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An Action Research Report
By Anthea Johnson and Amanda Partlo

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Abstract

The purpose of our research was to determine what impact participating in regular number talks, informal conversations focusing on mental mathematics strategies, had on elementary students' mental mathematics abilities. The research was conducted in two urban fourth grade classrooms over a two month period. The data sources included a pre- and post-questionnaire, surveys about students' attitudes towards mental math, a pretest and a posttest containing addition and subtraction problems to be solved mentally, teacher reflective journals, and student interviews. The results of our research indicate that participating consistently in number talks had a positive effect on students' mental mathematics abilities and the problem solving strategies they were able to articulate. Recommendations based on the results of the investigation include adopting brief number talks as an essential component of elementary mathematics curricula, thus allowing students many opportunities to solve problems mentally and to discuss their reasoning.

Consider the problem thirty-nine plus thirty-nine. Many of us learned to solve double-digit addition problems by first adding the numbers in the ones place: nine plus nine equals eighteen. We carry the one from eighteen and add that to three plus three to get seven. Seven is actually seventy, and we add that to eight to get the answer of seventy-eight. However, we could also simply add forty to forty to get eighty and then subtract two to get the same sum. Although both strategies yield the same answer, solving arithmetic with memorized procedures is quite different from using relationships between numbers to make computations. While the former method involves the use of memorized procedures with little thought to why they are being performed, the latter involves having a strong understanding of numbers and possessing what is referred to as *number sense*.

Possessing “number sense” means having an understanding of relationships among numbers and is considered a foundational skill of mathematics (Tsao, 2011). According to Tsao (2011), “Number sense refers to a person’s general understanding of numbers and operations along with the ability and inclination to use this understanding in flexible ways to make mathematical judgments and to develop useful and efficient strategies for managing numerical situations” (p. 2).

After our first number talk in our graduate level mathematics course, Methods and Materials in Mathematics, we wondered about the process through which students learn to think about and solve problems. We reflected on how we learned math ourselves, and we came to realize that we learned to solve problems largely through strict procedural methods and rote memorization. Often we solved arithmetic problems using specific procedures without understanding *why* we were performing these functions or what they meant. During the number talk in our mathematics course, many of our colleagues used more creative strategies that we had overlooked while we stuck to the standard “carrying and borrowing” methods. A few strategies they utilized when solving double-digit addition and subtraction problems included breaking numbers down into tens and ones, adding up in smaller and easier to compute chunks, adding up when subtracting, and adjusting one number to create an easier problem. We discovered that many of the more innovative strategies were generally easier and more accurate than the procedural methods that we used.

Following our number talk experience, we wondered which strategies would work best to build number sense in ourselves and in our fourth grade students at our student teaching sites. How could we encourage students to use and understand a variety of strategies? How could we help students teach and learn from each other as they solved mental math problems? We began to devise our action plan, and in the process, we identified our overarching research question: “What impact will participating in regular number talks have on fourth grade learners’ mental math computation abilities?

Several articles, reports, and studies were critical to formulating and launching our research. We first wanted to gain an overview of number sense in order to better understand its importance to students’ mathematics achievement. Jordan, Glutting, & Ramineni (2010) assert that number sense begins developing well before children enter school (p. 82). Their study, which involved students in the first and third grades, suggested that number sense was a “powerful predictor of later mathematical outcomes” (p. 86) and that students who possessed strong number sense had higher overall mathematical achievement and did better in both written computation and applied problem solving.

Having number sense is critical to understanding mathematical concepts, yet it is frequently lacking in many of today's schoolchildren (Tsao, 2011). Multiple studies have shown that number sense is underdeveloped largely due to the increased emphasis on algorithmic operations (O'Nan, 2003; Parrish, 2010; Tsao, 2011; Yang, 2002). Students may possess the procedural skills to solve problems, yet many lack the conceptual knowledge about how or why they perform certain procedures. Number talks are short classroom discussions involving purposefully selected math problems that are designed to help students develop mental computation strategies; students solve all problems in their head and are encouraged to use multiple strategies while solving problems accurately, efficiently, and flexibly (Parrish, 2010). According to Parrish (2010), "*Accuracy* denotes the ability to produce an accurate answer; *efficiency* denotes the ability to choose an appropriate, expedient strategy for a specific computation problem; and *flexibility* refers to the ability to use number relationships with ease in computation" (pp. 199-200).

Number talks have been used as a way to improve number sense and conceptual understanding while helping students see the relationships between numbers. Solving problems mentally and then discussing them in an open format, where the focus is on the process rather than the answer encourages learners to build on these number relationships to solve problems rather than to rely on memorized procedures (Parrish, 2010; Parrish, 2011). Number talks give students opportunities to develop their conceptual understanding of mathematics rather than merely solve problems using memorized procedures (O'Nan, 2003). Students with well-developed number sense are better able to think logically, critically, and flexibly, and they utilize more efficient problem-solving strategies, all of which are vital 21st century skills (Yang, 2002).

Number talks include five essential components: the classroom environment and community, classroom discussions, the teacher's role, the role of mental math, and purposeful computation problems (Parrish, 2010, pp. 10-15). The classroom environment should be based on acceptance and understanding so that children feel safe and comfortable to freely participate and try new strategies (Parrish, 2010). In Yang's (2002) study, he cites research advocating that "the best way to help children develop number sense is through process-oriented activities in a comfortable classroom environment (which) encourages children to think, probe, communicate, and discuss" (p. 152). He also found that number sense develops best when the focus is consistent and frequent.

Classroom discussions are at the heart of number talks and all answers, both right and wrong, are recorded and reviewed; wrong answers are viewed as opportunities to correct misconceptions and to investigate further (Parrish, 2010). Additionally, the teacher's role in number talks is one of facilitator, keeping the discussion focused on math and asking questions meant to guide, promote, and stimulate student thinking (Yang, 2002). Tsao (2011) asserts, "The teacher is (the) most critical factor in establishing a climate for curiosity and enjoyment of mathematics (p. 3).

Mental math computations are another important component of number talks because doing math without pencil and paper encourages students to build on number relationships to solve problems rather than by relying on memorized procedures. By focusing on numeric relationships to solve problems, students are able to compute more efficiently, flexibly, and accurately (Parrish, 2010). The last essential element of number talks includes selecting purposeful computation problems: "The teacher's goals and purposes for the number talk should determine the numbers and operations that are chosen. Careful planning before the number talk is necessary to design ‘just right’ problems for students” (Parrish, 2010, p. 14). Number talks should include a common focus and incorporate problems that lend themselves to a common strategy.

The National Council of Teachers of Mathematics (1989) notes that children with good number sense (1) have well-understood number meanings, (2) have developed multiple relationships among numbers, (3) recognize the relative magnitudes of numbers, (4) know the relative effect of operating on numbers, and (5) develop referents for measures of common objects and situations in their environments (Focus section, para. 2). Number sense is vital to learning and understanding mathematical concepts and must be developed and encouraged early on (Jordan, Glutting, and Ramineni, 2010, p. 82). In addition, children with well-developed number sense are better able to solve problems in everyday contexts (Jordan, Glutting, and Ramineni, 2010, p. 86).

With the growing emphasis on helping students cultivate number sense in order to equip them with the necessary mathematical skills to transfer their knowledge and understanding to real-world problems, some teachers implement routine number talks, which are described as “classroom conversations around purposefully crafted computation problems that are solved mentally…(and) are designed to elicit specific strategies that focus on number relationships and number theory” (Parrish, 2010, p. xviii). Number talks give students opportunities to develop their conceptual understanding of mathematics rather than merely solving by memorized procedures (O’Nan, 2003).

Jordan, Glutting, & Ramineni (2010) found number sense to be a “powerful predictor of later mathematical outcomes” (p. 86). This study included children in first and third grades and measured number sense based on three key areas: counting, number knowledge, and arithmetic operations. The authors also concluded that number sense seemed to have an even bigger impact on applied problem solving than it did on calculation, which assessed conventional operations and procedures. In Tsao's (2011) research on number sense, teachers stated that the students who had better number sense were able to think more flexibly and logically, which enabled them to utilize more efficient problem-solving strategies (p. 6).

Aksu (1997) found that students scored highest on the operations test and lowest on the problem-solving test, leading the researcher to conclude that it is possible for students to have procedural skills while lacking conceptual understanding. O'Nan (2003) found this to be true, as well: "A teacher in a large suburban elementary school in East Tennessee found that her fourth grade students had poor number sense and relied almost solely upon algorithmic procedure to solve math problems" (p. 3). This research has revealed that although students may obtain a correct answer, it is completely possible that they do not know how or why they follow certain procedures. Tsao (2011) found similar results demonstrating that when using traditional formulas for solving problems, students often did not understand the numbers or the operations.

Many sources agree that students with a strong number sense have a better understanding of mathematical concepts and relationships, which "helps children make judgments about the reasonableness of computational results and of proposed solutions to numerical problems" (NCTM, Focus section, para. 2, 1989). However, many students lack this number sense, and instead "view mathematics as a collection of rules and procedures to memorize, rather a system of relationships to investigate and understand (Parrish, 2011, p. 198).

In order to move past rote procedural knowledge and to help children cultivate their own number sense, teachers must be armed with the tools and resources needed to promote the development of number sense in their students. There is ample research indicating the importance of giving students opportunities to improve number sense and supporting the use of consistent number talks to do so (O'Nan, 2003, Parrish, 2010; Tsao, 2011; Yang, 2002.) However, the search for literature on this topic found only one study (O'Nan, 2003) that actually substantiated the implementation of daily number talks with pre- and post-data.

O'Nan's (2003) study sought to determine if daily number talks would lead to an increase in the number of strategies students could use to solve a given problem and whether an increase in known strategies would produce greater mental math achievement. After just six weeks of daily number talks, students were able to name and use more than twice as many math strategies than they could previously, and the speed with which they could mentally calculate two-digit addition problems increased significantly.

Many strategies can be used to solve mental arithmetic problems, and students that have a wide variety of strategies at their disposal are able to solve problems more efficiently, flexibly, and accurately than their counterparts holding a smaller repertoire of strategies (Parrish, 2010). However, students in elementary school often employ few central strategies for mathematical operations. For example, third-graders tend to use one of two strategies when adding and subtracting (O'Nan, 2003). The first involves deconstructing tens and ones in each of the numbers, which has been named 1010, as cited in O'Nan's (2003) action research, . The second involves counting up or down by tens from a base number that has not been split, called N10 (O'Nan, 2003). An example of the N10 strategy can be shown in the following solution for 21+32: 21+30=51; 51+2=53. O’Nan also notes that “Although the (1010) strategy is initially easier to learn, the (N10) strategy is both more efficient and accurate once it has been mastered” (p. 10). Students using the 1010 strategy answered only 64% of mental arithmetic questions correctly, while 94% of those using the N10 method answered correctly (p. 10).

In order to help students develop number sense, teachers must be intentional in their planning and instruction and give students sufficient opportunities to work through and discuss mental math problems (Parrish, 2010). A key way to do this is to encourage students to solve problems in at least two different ways and have them share strategies with each other in a comfortable and supportive environment (Parrish, 2011). Providing opportunities for problem-solving and math exploration is key to helping students develop an understanding of numbers, operations, and numerical relationships (Tsao, 2011). When used regularly for six weeks in a fourth-grade classroom, number talks proved to have a significant effect on student strategy use and mental math speed when adding two-digit numbers (O’Nan, 2003). It is hoped that these results are replicated in similar studies in order to support and justify the use of daily number talks in the elementary classroom.

In our action research, we implemented ten number talks focusing on five addition and five subtraction strategies. We both noticed that in our fourth grade classrooms at our student placement sites, students seemed to rely heavily on traditional algorithms involving carrying and borrowing. They had been taught to perform these functions at a young age, and it was difficult for the students to stray from using these methods. Their number sense was lacking, as well, as observed in our students’ inability to explain their thinking when solving problems or to describe why they performed certain operations. In addition, mental math was a relatively foreign concept to our students, as they had learned almost exclusively to solve math problems using pencil and paper.

Each number talk session was linked to a particular strategy from Shelly Parrish's (2010) text *Number Talks: Helping Children Build Mental Math and Computation Strategies*. We used this source purposefully in our planning to ensure we were studying a variety of problems and strategies. We then examined the impact that the number talks had on our fourth grade students. We sought to investigate what impact participating in regular number talks will have on our fourth grade learners' mental math computation abilities.

The research took place in two separate urban schools in a Midwestern state. The first school, Pine Lake (all names of people and places are pseudonyms), serves approximately 700 students in grades four through eight. Eighty-three percent of the students are Caucasian, 7% are African American, 6% are Asian, and 4% are Hispanic. Nine percent of the students at Pine Lake qualify for free or reduced lunch, and 2% are considered English Language Learners. The Pine Lake fourth grade classroom consisted of 32 students and devoted sixty minutes of instruction to math each day. The second classroom is located in a school called Oakdale. Oakdale serves approximately 500 students in kindergarten through fifth grade. Twenty-two percent of the students are at Oakdale are Caucasian, 26% are African American, 27% are Asian, 23% are Hispanic, and 2% are Native American. Of these students, 84% qualified for free/reduced lunch, and 35% were classified as English Language Learners. The Oakdale classroom consisted of 22 students and allotted between sixty to ninety minutes of mathematics instruction per day.

Description of Research Process

Our number sense intervention and action research included a total of ten number talks, five focusing on addition strategies and five focusing on subtraction strategies. Each talk consisted of two similar problems that could be solved using that day's target strategy. In order to find out if regular number talks would increase our student's strategic approaches to mathematics we collected data from the following sources; pre and posttests, questionnaires, interviews, and anecdotal notes in journals.

Before beginning our intervention, however, we first wanted to assess our students' attitudes about and beliefs towards solving math problems, particularly mental math computations. We administered questionnaires that included four statements to be answered anonymously using a Likert scale. The statements included: "There is usually one right way to solve a math problem," "It is important to be able to solve problems in my head," "In math, I use different strategies to solve different problems," and "I feel confident solving double-digit addition and subtraction problems in my head" (see Appendix A).The fifth question on the survey was open-ended and asked students to list or explain as many strategies for solving addition and subtraction problems as they could. We provided a brief written description of a strategy in the questionnaire ("Remember, a strategy is a method that you use to help you solve a problem") and gave an example orally, as well. Both researchers read the questionnaire aloud to ensure that reading ability was not a deterrent in completing the survey. The same questionnaire was given both pre- and post-intervention to track students' attitudes and beliefs and to measure any possible changes in students' responses.

The next step of our action research involved administering a pretest. The purpose of the pretest was to assess the students' abilities to solve math problems mentally. Students were presented with a posttest with new problems to solve that were similar to the pretest and based on the strategies used throughout the invention, The posttest was given following the conclusion of the ten number talks. During both tests, we wrote three double-digit addition and three double-digit subtraction problems on the board one at a time, for a total of six problems. Each problem could be solved using a specific target strategy (although students could certainly solve the problem using a different method). For example, the first question for both the pretest and the posttest involved a problem that students could solve mentally using the Making Friendly Numbers strategy, 26+49 and 39+13, respectively (see Appendix B) and target strategies used in the number talks). In both questions, students could round to a "friendlier" number to solve the problem; for example, in 26+49, the student could add 26 to 50 to get 76 and then subtract 1 to get the answer of 75. Students were directed to write their answers and a brief explanation of how they arrived at their answers; they were told they could draw a picture, describe in words, or use another method to explain their strategy. We explicitly asked the students to solve the problems mentally and not to write the problems down on their papers as the paper was only for writing the answers and explaining their strategies.

We both facilitated the number talks using an identical set of predetermined problems intended to cover five separate addition strategies and five separate subtraction strategies (see Appendix C). The research at Pine Lake spanned the course of about four weeks, with number talks occurring regularly on an every other day interval either two or three times a week. The number talks at Oakdale took place when the schedule allowed over the course of about eight weeks.

After we administered the pretest, we were then ready to begin the number talks. Number talks are designed to take a maximum of about fifteen minutes. They can be used as a warm-up for math class, as was the case for the Pine Lake classroom, or they can take place during different parts of the day as the schedule permits, as was the case in the Oakdale classroom. Number talks are best done when students are away from their desks and away from any temptation to use writing utensils to solve the problem procedurally, sitting on the floor while the teacher stands in the front of the class.

We began by writing the problem on the board/chart paper and then gave the students time to solve the problem in their heads. Students indicated that they had solved the problem using what is called a “silent thumb,” which means that students held their balled fists near their stomachs and gave a silent thumbs up to indicate they had solved the problem; for each additional strategy, students held up another finger. For example, a student would hold up his/her thumb if he/she solved an addition problem using the traditional carrying method, a forefinger if said student also solved it by rounding to a friendly number, and a third digit the problem was solved the problem by adding up it up in chunks. The purpose of the silent thumb was so students could show the teacher they had solved the problem in *x* number of ways and to encourage students to continue looking for additional avenues to arrive at an answer while not distracting other students.

After enough time had passed for nearly all students to have at least one finger up, about 2 minutes or so, volunteers were then called upon to share one method that they used to solve a problem. The focus of number talks is always on the method used and *how* the students arrived at the answer, not on the answer itself. In the classroom at Pine Lake, students were invited to the Smart Board to record their answer while explaining their thinking to the class. At Oakdale, where Smart Board technology was not available, students explained their strategy while the teacher recorded their method step by step on chart paper.

We facilitated the number talks by asking probing questions to encourage students to think critically about their method and to help them clarify their thoughts for the rest of the class. We believed it was important for students to be able to identify and verbalize their mental processes so that they could build a repertoire of accessible strategies and to be confident when using them. After three to four students had been given the opportunity to share each problem, we then wrapped up the number talk by introducing the target strategy, while also emphasizing it was only one of many that could be used. We proceeded to explain the strategy and when it would be most appropriate to use; if a student had not yet demonstrated that particular method during the number talk, we would then show how to solve both problems using the target strategy. Each number talk included two problems; either both addition or both subtraction.

During the number talks, the cooperating teacher took notes to document the approximate number of strategies students used (e.g. "Students seemed to hold up more fingers during the second problem than the first" or "I saw more than half the class had at least three strategies during this number talk") and recorded anecdotes about any additional relevant information, such as misconceptions or common errors, emerging patterns noticed, and perceived level of engagement. After each number talk, we recorded information that included our cooperating teachers' notes and our own observations in a reflective journal.

A fourth data source consisted of student interviews. Following the conclusion of the number talks and the administration of the posttests, we selected six students of varying mathematical abilities to interview in order to gain a fuller and more comprehensive understanding of their views on the number talks and their effectiveness in helping them solve problems mentally. The interviews also helped us understand if students felt the number talks helped them learn and use more strategies when solving problems. Students were selected based on their overall performance in math and with number talks; we each selected two advanced learners, two intermediate students, and two struggling students, for a total of twelve students, to ensure a wide range of responses that represented the classroom as a whole.

In the interviews, students were asked the following questions: 1. Name/explain as many addition strategies as you can. 2. Name/explain as many subtraction strategies as you can. 3. Rate your ability to solve math problems in your head after doing number talks (better) (the same) (worse) 4. Do you feel that you learned new strategies for solving addition and subtraction problems from your classmates? 5. What did you like best about number talks? 6. What did you like least about number talks? (See Appendix D). Both researchers typed the students' responses verbatim as the interviewees answered, and the data were then coded to look for trends and to identify themes that emerged.

Our goal is to improve our students' computational abilities, by teaching students different strategies and teaching how to verbalize their strategies. We will be analyzing the culminating data from these sources in the next section to help us understand if regular number talks were beneficial to students' mental math computation abilities.

Data Analysis

Data were collected using a variety of sources to ensure both qualitative and quantitative measurements were included. The four data sources included a pre- and post-intervention questionnaire, a pretest and a similar posttest containing six addition and subtraction problems to be solved mentally, anecdotes recorded in our reflective journals, and student interviews.

We wanted students to know that their thoughts and opinions were valued and sought to assess students' views on mental math and strategy use as well. Subsequently, before launching into the first number talk, we first administered an anonymous questionnaire. The first four questions on the questionnaire provided students with a statement that they were asked to rate on a Likert scale (see Appendix A); these questions were meant to elicit students' thoughts and beliefs about mathematics, particularly mental math. Students were also asked to explain or name all of the addition and subtraction strategies they knew. Both a written explanation and an oral example of a strategy were given before we read the questionnaire aloud in our respective classrooms.

Upon conclusion of the ten number talks, students were once again given the same questionnaire. The median and mode were then calculated for each statement. We recorded changes that were found in the responses from the pre-questionnaire to the post-questionnaire and analyzed the results.

The first questionnaire statement read: "There is usually one right way to solve a math problem." A change was observed in the mode in both classrooms. Students at

Oakdale most commonly gave this statement a 2 (disagree) on the pre-questionnaire, but on the post-questionnaire they were most likely to respond with a 1 (strongly disagree). When asked the same question, Pine Lake students responded most often with a 4 (agree) on the pre-questionnaire, but this changed to a 2 (disagree) on the post-questionnaire.

When we combined the data from both the Oakdale and the Pine Lake classrooms, a sizable change was noted in the mode from 4 to 1. While most students in both classrooms agreed with the statement “There is usually one right way to solve a math problem” prior to the intervention, they most frequently strongly disagreed with this statement following the number talks. The data seem to indicate that while students at Oakdale and Pine Lake originally tended to think there was usually one right way to solve a mathematics problem, they were able to see that there are actually multiple ways to solve mathematics problems after participating in number talks.

Statement two read: “It is important to be able to solve math problems in my head.” At Oakdale the mode response on the pre-questionnaire was a 4 (agree); following the intervention, however, the majority of students ranked this statement with a 5 (strongly agree). The most frequent response at Pine Lake was a 3 (neutral), which shifted to a 5 (strongly agree) after the intervention. When the data between classes were combined, we saw that students most frequently agreed with this statement on the pre-questionnaire, but on the post-questionnaire, students were more apt to strongly agree. This suggests that the intervention helped students see the importance of mental math, a key purpose of number talks.

The third statement on the questionnaire stated: “In math, I use different strategies to solve different problems.” When using the mode, we found that both Oakdale and Pine

Lake students responded during the pre-intervention period with a rating of a 5, but post-intervention most students gave this statement a 4. Although we were surprised to see this shift from strongly agree to agree, we were pleased that students continued to agree with the statement. We speculated that perhaps students were now more aware of multiple strategies but that they still chose to use certain strategies most often. Posttest results (discussed below) suggest that even following the intervention, many Oakdale students continued to use the standard algorithms of carrying and borrowing as their go-to strategies.

The fourth and final statement on the questionnaire stated: "I feel confident solving double-digit addition and subtraction problems in my head." Prior to the intervention, 11 students at Oakdale rated this statement with a neutral ranking, 6 students agreed with the statement, and 12 students strongly agreed, resulting in a mode of 5. We found it interesting that no students ranked this statement with a 1 or a 2, because that would indicate that they did not feel confident solving addition and subtraction problems mentally. Eighteen students, or 62%, agreed or strongly agreed with the statement before participating in the intervention.

Following the intervention, we observed more variation in the Oakdale students' responses on the fourth questionnaire statement. Two students indicated they strongly disagreed, 2 noted they disagreed, 7 rated it as neutral, 7 agreed, and 13 strongly agreed. We found it interesting that after the number talks intervention, 4 students disagreed or strongly disagreed with the statement, although none had disagreed prior to the intervention. We speculated that perhaps students were now more aware of shortcomings in their computational abilities after several weeks of practice with mental math.

However, the majority, 20 of the 31 students, or 65%, agreed or strongly agreed with the statement, an increase of 3% from pre- to post-intervention. Again, the mode was 5.

Pine Lake saw a decrease in confidence in students' self-perceptions of their abilities to solve double-digit problems mentally. Most students rated their confidence a 5 on the pre-questionnaire and that rating dropped to a 3 on the post-questionnaire. One purpose of the intervention was to raise their confidence by practicing verbalizing their strategies; however, it is possible that students were now more aware of their deficiencies in solving mathematics problems mentally.

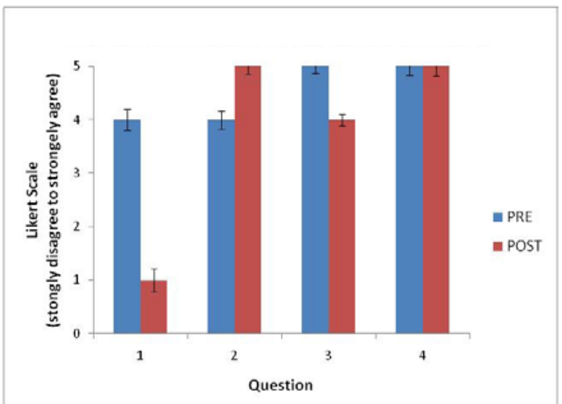

Figure 1. Combined classroom pre- and post-questionnaire results

In addition to analyzing data from the first four statements on our questionnaire, we also tracked how many strategies students listed pre-intervention and post-intervention and looked for any notable changes in their responses. For example, we found that students were much more detailed when naming/listing strategies following the number talks intervention. We also found that students were much more likely to name the strategy in the second questionnaire, whereas in the first questionnaire students tended to explain with a drawing, an example, or in words.

In the Oakdale classroom, a total of 27 students listed a total of 41 strategies on the pre-questionnaire, averaging one and a half strategy per student. In the first questionnaire administered to Oakdale students, only 4 of the 27 students (15%) actually named a strategy; the others explained the strategies, most often by giving an example, such as displaying a number line, solving using standard algorithm, or showing how to break the numbers into place value. The students demonstrated that although they may have known multiple strategies, they did not necessarily have a label for them.

In the post-intervention questionnaire, students were much more likely to name the strategy rather than explain it or show an example. Sixty-six percent of students in the post-questionnaire named strategies using language we had used throughout the number talks; for example, listing “Adding up,” “Counting Back,” “Traditional way,” or “Breaking each number into place value.” In addition, 29 students listed or named a total of 132 strategies on the post-questionnaire, more than three times as many given in the pre-questionnaire, for an average of more than four strategies per student.

In the Pine Lake classroom, a total of 23 students completed the first questionnaire, and a total of 30 strategies were recorded, averaging 1.3 responses per student. Nearly half of their responses (43%) involved carrying or borrowing, and ten of the 13 carrying and borrowing responses were described with an illustration. All other responses on the pre-questionnaire were unrelated to strategies, for instance, “in my head,” or “I just knew it.”

The post-questionnaire was administered to 20 students, and a total of 54 responses were collected, averaging almost three strategies per student. At Pine Lake, student responses tended to be more detailed and specific when compared to the pre-questionnaire responses. Although some students still responded with vague answers, more students were able to name strategies, such as “Place Value,” “Borrowing,” and “Adding Up.”

Our second data source included both a pretest and a posttest with six addition and subtraction problems (see Appendix B). Students were directed to solve the problems mentally and to record both the answer and how they arrived at that answer, or what strategy they had used, on a sheet of paper; they were also explicitly told not to use the pencil and paper to solve the problem. Each student was given a ‘1’ for a correct answer and a ‘0’ for an incorrect response; they were also given a total score of how many problems they got right out of six. We then analyzed the data for trends and patterns and calculated the mean, median, and mode number of problems students answered correctly on both tests.

In the Oakdale classroom, 29 students completed the pretest (see Table 1). The (+) or (-) next to the question number indicates whether the problem involved addition or subtraction.

Table 1

Oakdale Pretest and Posttest Results

Question	1(+)	2 (+)	3 (+)	4 (-)	5 (-)	6 (-)
% answering correctly, pretest	72%	79%	72%	48%	48%	38%
% answering correctly, posttest	90%	93%	97%	70%	90%	60%

A majority of students at Oakdale answered the first three questions, all addition problems, correctly. They struggled more with the subtraction problems: fewer than half of the students answered each of these three problems correctly. Problem 6, 71 - 36, seemed to be the most difficult, with only 38% of students giving the right answer. Students' scores ranged from 1 student scoring a zero to a perfect six, earned by 4 students. The median number of problems answered correctly was four and the mode was also four.

Thirty students at Oakdale completed the posttest (see Table 1). Again, students scored better on the addition problems than they did on the subtraction problems: 90% of students or higher answered each of the three addition problems correctly. The most difficult problem was, again, number 6, a subtraction problem: 61 - 29; 60% of students got this problem right, which marks a 22% increase from the lowest percentage answering a similar question correctly on the pretest. Students' scores ranged from a minimum of three, earned by 3 students, to 15 students earning a perfect score of six. The median number of problems answered correctly was 5.5 and the mode was six.

We saw great gains in the Oakdale classroom from the pretest to the posttest; while only 4 students earned a perfect score on the pretest, 15 students earned a perfect score on the posttest. Upon closer review, however, we noticed that many students recorded "standard algorithm" as the method they used to solve the problems on the posttest, and it looked as though many used the traditional carrying and borrowing methods to solve the problems rather than using one of the mental math strategies that they had learned. Although it was not one of the target strategies taught through the intervention, students had learned about standard algorithm in other areas of the curriculum; it is likely some students used this as their default strategy for solving the problems on the posttest. Overall, students were much more likely to name and/or explain strategies used on the posttest than on the pretest.

At Pine Lake, 21 students completed the pretest; two students' data were excluded after parents declined their child's participation. Table 2 reflects the remaining 19 students' mean scores per question. The students were far more successful with the addition section when compared to the subtraction section. The median number of questions answered correctly on the pretests was 3.

Table 2

Pine Lake Pretest and Posttest Results

Question	1(+)	2 (+)	3 (+)	4 (-)	5 (-)	6 (-)
% answering correctly, pretest	79%	74%	47%	32%	16%	16%
% answering correctly, posttest	76%	76%	82%	59%	59%	53%

Seventeen Pine Lake students were included in the posttest results, 3 of which answered all six problems correctly. Overall the scores on the posttest were higher than on the pretest, with the exception of question 1 which declined by 3%. Question 2 had a marginal increase of 2%, while questions 3 through 6 all increased on average 35.5%.The median number of problems answered correctly on the posttest was 5, for an increase of 2 points per student.

At Pine Lake, there were 15 useable individual pre and posttest data to evaluate. After careful consideration of their individual scores, we found that 1 student scored

100% on both tests, 10 students' scores improved on the posttests, 3 students' scores remained the same, and 1 student's score declined on the posttest. Students seemed to have a better understanding of strategy usage and were more skilled at using the language surrounding addition and subtraction strategies after the intervention, as evidenced by their responses on the pre and posttests. Students were more likely to explain their strategies on the posttest by labeling the strategy or by showing an example of one of the strategies that they had learned.

The third data source, our journals, were used to record anecdotes and reflections on our number talks. We wrote journal entries after each number talk, for a total of ten entries each. Journal entries included: information on student engagement and participation; overall strategy usage, including popular and recurring strategies; student errors and misconceptions; cooperating teacher remarks and observations; and other data deemed to be relevant to the number talks. After the conclusion of the intervention, we examined our journals looking for trends, coding responses, and highlighting key information.

Anthea, the researcher at Oakdale found that students were eager to participate and share their answers from the first day. For each problem, at least half of the class, and, more often, the vast majority, raised their hands in hopes of sharing. Although class participation was generally high, she noticed that a few students never raised their hands to volunteer. These students seemed to struggle in mathematics class. Anthea considered that perhaps they were not as confident in sharing their thinking in front of the class and wondered if a small group number talk would benefit these students and others like them.

Anthea also tried to record recurring strategies, observing that standard algorithms of carrying and borrowing, Breaking Each Number into Its Place Value, and Making Friendly Numbers seemed to be the most popular; she noted that standard algorithms seemed to be "drilled" into the students, as it was often the first strategy demonstrated and was used in all ten talks.

After participating in a few number talks, Anthea observed that students were regularly using strategies that had been covered in previous talks to solve new problems. By the end of the intervention, they were also indentifying strategies by their "official names." In addition, participation continued to be high. In her journal, Anthea noted: "Today when I told students we only had one number talk left, someone asked if we would do them next with multiplication and division. I'm starting to see that number talks are making a difference in students' mental math abilities and strategy usage."

Amanda conducted her research at Pine Lake and had her cooperating teacher use a table to track participation during each talk. Both she and her cooperating teacher noted that most students stayed engaged throughout the number talks and that they were generally excited when it was time to transition to a number talk. They seemed to enjoy sharing their thinking, and each talk had approximately six different volunteers. Amanda also tracked popular strategies and found her students most often used standard algorithms, Adding Up in Chunks, and Making Friendly Numbers when solving the problems.

In her journal entries, Amanda remarked that the addition number talks were, overall, very effective for establishing conversations that boosted number sense. During the first half of the intervention, she observed that students listened to others' methods and tried new techniques after seeing their classmates demonstrate different strategies, although standard algorithm was usually the first method demonstrated. However, the same was not found with the subtraction talks. Amanda noted that students struggled with subtraction problems when solving them both mentally and on paper, as seen by their results on an unrelated subtraction quiz. It was not uncommon for students to come up with three different answers during a subtraction number talk. They often tried methods that were not appropriate for the problem and had a difficult time transferring recently learned strategies to new problems. Amanda did note, however, that students seemed to be more proficient during the final subtraction number talks, frequently using strategies such as Counting Back and Adding Up. They also made great gains on subtraction mental math from the pretest to the posttest, where the average number of students responding accurately increased by an average of nearly 36%.

The fourth and final data source was student interviews (see Appendix D). In order to gain a more complete understanding of students' views on number talks and to assess whether students felt number talks were effective in helping them learn new ways to solve problems mentally, we each selected six students to interview, for a total of twelve students. The interviews were performed in the hallway outside of the classroom and interviewees' responses were typed verbatim. We were intentional on our selection of the students, choosing two students performing on the higher end of the spectrum in mathematics, two average students, and two learners performing on the lower end of the spectrum in mathematics. We hoped to ensure a full representation of our diverse classrooms.

We asked students to list as many addition and subtraction strategies as they could and to then rate their ability (better, the same, or worse) to solve math problems mentally after the number talk intervention. We were also interested in finding out whether students felt they had learned new strategies for solving problems from their classmates and what they liked and did not like about number talks. After conducting the interviews, we then coded the responses to look for trends and emerging patterns.

Five of the interviewees from Oakdale were able to name or explain three addition strategies and one student named four. Four of the students named three subtraction strategies, while two were able to list four. All six students included "Standard Algorithm," "Stacking," or "Traditional Method" as one of their addition strategies and as one of their subtraction strategies; it was nearly always used as one of the methods demonstrated during the number talks, even as students learned more strategies. This trend demonstrates how ingrained standard "Carrying" and "Borrowing" may be in elementary students who likely first learn to add and subtract using these methods. We saw that even after students were introduced to and learned new—often easier and more efficient—strategies, they still relied heavily on standard algorithm, even when performing operations mentally.

All six Pine Lake students seemed confused when asked to list as many strategies as they could because they had just finished the questionnaire the day prior, and it was clear they did not have the language necessary to name the strategies. All of the students named "Borrowing" and "Carrying" and one student explained different ways of breaking the problem into smaller numbers and gave many examples of how he would do it; no one said they did it in their head or they just knew it.

The six Oakdale students rated their ability to solve math problems mentally as "better," and in the case of a few students, "Way better." All but one student from Pine

Lake rated their abilities as better. This student rated his ability as “the same.”

We were initially drawn to the idea of number talks because of the creative strategies we saw our university classmates utilize while participating in our first number talk in our Methods and Materials in Mathematics course; we hoped that our fourth grade students would also find inspiration in their classmates’ innovative methods. All six students at Oakdale agreed that they learned new strategies for solving addition and subtraction problems from their classmates. One student added that it was helpful to see others solve the problems in different ways and that seeing her classmates give the wrong answer made her feel better about her own mistakes. All interviewees from Pine Lake also agreed that they learned from their classmates during the number talks.

The final two questions of the interview asked students what they liked best about number talks and what they liked least about number talks. All students interviewed at Oakdale had favorable views on number talks. They seemed to enjoy the opportunity to share their thinking with their classmates and the challenge of solving problems without a pencil and paper. A few also expressed enjoying the opportunity to use the Smart Board. The students interviewed at Pine Lake liked sharing their strategies, getting to hear others students’ techniques, and learning different ways to look at a problem.

The final interview question asked students what they liked least about number talks. Two students from Oakdale could not come up with a reason why they did not like number talks. One student expressed the fact that not everyone could share as her least favorite part and another stated that some of the strategies were hard to learn. At Pine Lake one student expressed not liking that number talks often took place at the end of the day because it interfered with their FLEXtime, when students were given time to play math related games and computer time. Others said there was not anything they disliked.

We were encouraged by interviewees' positive feedback and by the fact that all students rated their ability to solve problems mentally as better. Hearing that students learned new strategies from their peers was a promising finding, as well. Overall, the 12 students selected for the interviews expressed having positive and rewarding experiences during the number talks intervention.

After analyzing all four of our data sources, we have concluded that participating in regular number talks had a positive impact on our fourth grade learners' mental math computation abilities. Students were able to list more strategies or explain their thinking more specifically on both the posttest and the post-questionnaire, indicating they were aware of a wider variety of methods used to solve problems; they were also more likely to recognize that mathematics problems can be solved multiple ways. Their posttest scores demonstrated that overall students could solve more problems correctly following the intervention. However, even though students knew and could name more strategies, they still relied heavily on standard algorithm to solve double-digit addition and subtraction problems. More experience using these strategies while performing mental math is needed in order for students to apply the strategies accurately, efficiently, and flexibly.

In the next section, we will discuss our plan of action based on what we have learned from our data. We will analyze the possible impacts our research will have on student learning and how our results will change our own practices. In our action plan, we will also make recommendations for potential future action research investigations involving number talks and mental math.

Action Plan

The results of our research demonstrated that number talks had a positive impact on our fourth grade learners' mental math computation abilities. Throughout the intervention, students encountered and became familiar with multiple strategies they could use to solve mental math problems accurately, efficiently, and flexibly. Although students knew and could name more strategies, many still relied on standard algorithms to perform double-digit addition and subtraction problems, even when other strategies would have been more productive. Students also showed greater accuracy when solving math problems mentally, as indicated by the results of the posttest, but, again, many still relied partially or solely on standard algorithms to do so.

Students demonstrated their understanding of relationships among numbers as they applied new and different strategies during the number talks. They also described their reasoning processes as they took turns sharing their strategies. Students realized that there is more than one way to solve mathematics problems but reported feeling less confident about their abilities to solve problems mentally. In addition, students expressed that they enjoyed learning strategies from their peers and had overall had positive experiences while participating in number talks; many even requested to continue them after the intervention was complete.

After witnessing the positive impact that number talks had on our students, we plan to continue facilitating number talks in our classrooms, selecting purposeful problems for students to solve mentally and then guiding discussions with their classmates. Number talks are appropriate for many elementary school settings and they can be done with addition, subtraction, multiplication, and division. They are an interesting and fun way to warm up for the days mathematics lesson and we plan to allot between ten and fifteen minutes two to three times a week for number talks in our classrooms.

In addition, we will also explore other ways that we can aid students in their development of number sense and will implement these exercises in the classroom. For example, students should have many opportunities to use estimation in real life situations, solve problems mentally, discuss and explain their reasoning, and employ a variety of strategies to obtain an answer. We plan to provide our students with many exposures to these activities.

During our number talk intervention we noticed that although class participation was generally very high, there were still a few students who rarely volunteered to share. It is likely that these students felt reluctant to participate due to a lack of confidence in using different strategies, particularly when demonstrating them in front of their peers. These students, and others like them, would benefit from a small group number talk. In a small group we can help students know when and how to utilize different strategies, while coaching them on how to explain their thinking and problem solving methods. For example, we could name and explain a target strategy, such as Adding Up in Chunks. We could then demonstrate the strategy, do a problem together with the students, and then provide another similar problem for students to do on their own, following the gradual release of responsibility model. The students would likely feel more comfortable in a small group of four or five students and would hopefully then feel confident to share in a larger setting; they would also better understand other students when they explained their reasoning and thinking processes.

We plan to share our results with other teachers and introduce them to number talks in the manner that we were first exposed--through active participation. We found it inspiring to learn new strategies and ways of thinking from our colleagues in our Methods and Materials in Mathematics course, and we will strive to pass this inspiration on to others by showing them creative methods to solve problems mentally. We plan to invite both fellow teachers and administrative professionals into our classrooms so that they can observe number talks in action. They will witness children participating actively in mathematics, discussing strategies, and explaining their thought processes with their peers. After participating in a number talk and then observing one in action, we hope that other teachers will see the benefits and will want to include number talks in their own classrooms.

Conclusions from the research and from our own results indicate that children need many and varied exposures to mental math exercises in order to confidently solve problems accurately, efficiently, and flexibly and to develop and increase their number sense (O'Nan, 2003; Parrish, 2010; Parrish, 2011; Tsao, 2011; Yang, 2002). Although a wide body of research exists supporting the effectiveness of helping children develop number sense on future mathematical success, more research is needed on the success of number talks in helping students cultivate their number sense (O'Nan, 2003; Parrish, 2010; Tsao, 2011; Yang, 2002). We recommend that future studies replicate our research to observe whether similar results are obtained in other classrooms. Future research involving other grades and settings would also be helpful in determining the effectiveness of number talks on mental math abilities. Additionally, we would like to implement further action research focusing on multiplication and division strategies in our classrooms. The results would aid us in determining the most effective ways to teach these operations to students and would highlight any misconceptions students have regarding multiplication and division.

It is clear that students need to be active participants in their learning and that in order to understand mathematical operations and why they perform them; they need to have many opportunities to solve problems mentally. Rote memorization and drill procedures have an adverse effect on students' abilities to thinking logically and flexibly and stifle the development of number sense. Mental math and shared reasoning, however, can help students see relationships among numbers while increasing their number sense. These exercises help students learn and apply a wide variety of strategies when solving problems.

Although it is still necessary to teach students standard algorithms, it should not be the focus of mathematics instruction. When learning to add and subtract, it would be more beneficial to first teach students alternative, more natural strategies so that when they do learn the traditional carrying and borrowing methods, they will have a better understanding of how and why these operations work and will come to rely less heavily on them in the future. In future action research we would like to measure and compare the number sense of students who first learn mathematical operations using traditional methods and the number sense of students who learn alternative strategies first. The results could help change the way that students are initially taught mathematical operations and would ideally lead to students developing strong number sense and experiencing greater academic success.

Our action research not only demonstrated positive outcomes for our students, but we experienced positive outcomes, as well. We now feel more empowered and equipped to continue forward in our own practice as educators. Through devising our research plan, implementing our intervention, and analyzing our results, we have learned to use research and data to drive our teaching methods and to respond to our students' needs. We look forward to using the results of our research to better ourselves as teachers and to execute future action research in our classrooms.

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Appendix A

Number Talks Questionnaire

Rate the following statements on a scale of 1-5.

1. There is usually one right way to solve a math problem.

1	2	3	4	5
Strongly disagree	disagree	neutral	agree	strongly agree

2. It is important to be able to solve math problems in my head.

1	2	3	4	5
Strongly disagree	disagree	neutral	agree	strongly agree

3. In math, I use different strategies to solve different problems.

1	2	3	4	5
Strongly disagree	disagree	neutral	agree	strongly agree

4. I feel confident solving double-digit addition and subtraction problems in my head.

1	2	3	4	5
Strongly disagree	disagree	neutral	agree	strongly agree

5. List/explain all of the addition and subtraction strategies that you know.

Remember, a strategy is a method that you use to help you solve a problem.
(Explain as best you can; you may use the back.)

Appendix B

Pretest and Posttest Problems

Students will be given 6 problems (three addition and three subtraction). They will be instructed to answer the problems mentally and record their answer, as well as how they got that answer, on a piece of paper. Allow approximately 2 minutes per question.

Pretest:

1. 26 + 49 (Landmark/Friendly Numbers)

2. 17 + 33 (Place Value)

3. 65 + 36 (Adding Up in Chunks)

4. 80 - 69 (Adding Up)

5. 50 - 24 (Adjusting One Number to Create an Easier Problem)

6. 71 - 36 (Keeping a Constant Difference)

Posttest:

1. 39 + 13 (Landmark/Friendly Numbers)

2. 16 + 38 (Place Value)

3. 32 + 55 (Adding Up in Chunks)

4. 90 - 39 (Adding Up)

5. 38 - 20 (Adjusting One Number to Create an Easier Problem)

6. 61 - 29 (Keeping a Constant Difference)

Appendix C

Number Talk Problem Sets

Addition strategies

Number talk #1: Target strategy--Making Landmark or Friendly Numbers

- 59+13
- 26+79

Number talk #2: Target strategy--Doubles/Near Doubles

- 39+39
- 26+27

Number talk #3: Target strategy--Breaking Each Number into Its Place Value

- 28+42 (20+8+40+2=60+10)
- 59+65 (50+9+60+5=110+14)

Number talk #4: Target strategy--Adding Up in Chunks (the focus is on keeping one addend whole and adding the second number in easy-to-use chunks)

- 28+24 (28+20=48, 48+4, 48+2+2=52)
- 73+58 (73+50=123+7+1=131)

Number talk #5: Target strategy--Compensation (when compensating, a specific amount is removed from one addend and then that exact amount is added to another addend.)

- 37+45 (40+42)
- 98+63 (100+61)

Subtraction Strategies

Number talk #6: Target strategy--Adding Up (show number line)

- 90-49 (1+40=41)
- 61-26 (4+30+1=35)

Number talk #7: Target strategy--Removal or Counting Back (show number line)

- 70-34 (70-30=40; 40-4=36)
- 94-56 (94-4=90; 90-30-60; 60-4=56; 4+30+4=38)

Number talk #8: Target strategy--Place Value and Negative Numbers

- 53-17 (50+3 - 10+7 = 50-10 = 40; 3-7 = -4; 40-4=36)
- 95-68 (90+5 - 60+8 = 90-60 = 30; 5-8 = -3; 30-3=27)

Number talk #9: Target strategy--Adjusting One Number to Create an Easier Problem

- 80-49 (80-40=40; 40-9=31) 80-49 (80-50=30; 30 +1 = 31)
- 62-45 (62-42=20; 20-3=17)

Number talk #10: Target strategy--Keeping a Constant Difference

- 91-46 (90-45=45: 91-1=90; 46-1=45)
- 88-52 (88+2=90: 52+2=54; 90-54=36)

Appendix D

Interview Questions

1. Name/explain as many addition strategies as you can.

2. Name/explain as many subtraction strategies as you can.

3. Rate your ability to solve math problems in your head after doing number talks

better the same worse

4. Do you feel that you learned new strategies for solving addition and subtraction problems from your classmates?

5. What did you like best about number talks?

6. What did you like least about number talks?