Expository Writing in Mathematical Thinking:
Reasoning and Proof to Communicate Story Problem Solutions

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Abstract

In this action research study of my fourth grade mathematics classroom, I investigated students’ use of expository writing in mathematical lessons as a means for explaining their thinking using reasoning and proof to communicate story problem solutions. I discovered that my teaching became explicit and intentional toward student need through whole group and individual instruction. My teaching also centered on students’ knowledge, use, and understanding of operations and strategies. I also learned that students preferred to work together as opposed to alone when working and solving story problems. I further noticed that students’ quality of reasoning and quality of their problem-solving solutions were inconsistent over time. As a result of this research I plan to provide more opportunities for student collaboration and more opportunities for mathematics writing as a means of exploring and discovering to learn content and concepts.
I have taught fourth grade for 10 years at two different schools, in two different districts, and in two different states. Both were schools with primarily low-socioeconomic minority students. Both schools’ lowest area of mathematics performance has been problem solving. Is this a mere coincidence or are there legitimate reasons for this trend? The traditional way of teaching mathematics does not seem to be working, and piecemeal snippets of ideas and programs are also not yielding results. It is imperative for myself and others who serve lower socioeconomic and minority students to improve students’ mathematical problem-solving skills. Teachers want students to learn, achieve, reason, and problem solve throughout all areas of their lives. In an ever-changing, fast-paced, technological society, being able to critically solve problems and contain thorough explanations is only going to be more relevant as students’ lives move forward.

The traditional approach of elementary mathematics education suggests a teacher-centered approach of teaching whole group and assigning problems that are primarily computation-based. Usually assignments are corrected and handed back, with little feedback as to what can be improved mathematically. Although this approach works for many students, the traditional approach lacks relevancy in my classroom and it does not work for my students. In order for students to become better problem solvers, they need to be reading, writing, and thinking. Students are more likely to become successful life-long problem solvers if they are exposed to real-life situations and problems.

Classrooms are structured as the teacher being the focus of attention. Walk into any classroom and look for the physical placement of the teacher’s desk. Is it in the front of the room? Are all the students focused on the teacher, or are they focused on one another? Teacher-
centered instruction needs to change. The old way is outdated and not considered best practice for today’s instruction.

My current students lack overall mathematical strategies and prior experiences, and they also are unable to explain the processes they used to solve problems. Students are unable to identify if their answer is correct or incorrect and whether it makes sense according to the work they have completed. Many students just want to place an answer on the paper and move on, and many teachers allow this as the normal status quo. These actions by students lead me to believe their prior experiences have involved basic computation. Also in my classroom when I ask for students to write and explain their mathematical thinking, students focus more on the answer than the thinking that lead to their final solution. Ultimately, it appears that most of my students believe writing about mathematics is more of a rote step-by-step process, rather than an attempt in mathematical reasoning.

The way mathematics is taught at the elementary level requires a paradigm shift. The traditional computation focus needs to be replaced with a problem solving approach with the held belief that math is thinking and the entire learning process social. When teachers view math as thinking, teachers will change what students are asked to do within the classroom, and more pictures, drawings, and explanations will be generated as students read and write mathematics.

Problem Statement

The students in my classroom lack mathematical strategies to solve story problems. They also are unable to explain the processes used to solve the problem. Students are unable to identify if their answer is correct or incorrect and whether it makes sense to the work they have completed.
Each day for bell work students have five problems to work on and ultimately complete. The last one is a story problem. Many students get stuck on reading it, then determining what is being asked, and what to do. When I ask for students to write and explain, they focus more on the what, than the why of the problem. It appears that most of my students believe writing about mathematics is more of a rote step-by-step process, rather than mathematical reasoning.

How can I improve the mathematical strategies students use to complete work on story problems and what are the implications of using expository writing as part of the process? My ideal school year would begin with students already having experience with various mathematical strategies. My ideal students would come equipped with strong social skills so that partner work and group work could be used as a means of working through harder more sophisticated story problems. Students would be motivated to learn and work. They would also be willing to keep working when situations and problems in mathematics become difficult. Students would have self-esteem and confidence to be risk takers and attempt work that is difficult and challenging.

Based upon my experience and research of teaching mathematics, I have been influenced by Vygotsky and his belief that learning is a constructivist and social process. Students learn from doing as well as from interacting with others. My classroom is set up for whole group, small group, and one-on-one interaction between peers and between teacher and student. I have a carpet up front for whole class gathering, tables where students work independently and in groups, and I have a table in the back of the room for small group work with teacher direction. In the later years of my short teaching career, Carpenter and Fennema (1999; 2003) have influenced my view and approach to teaching and learning mathematics. Their belief in Cognitively Guided Instruction and thinking mathematically has influenced changes to how I address the bigger
picture of learning mathematics; math is thinking. They note, “Mathematics involves ways of
thinking, including ways to generate ideas, express and represent them, and justify that they are
true” (p. v). These ideas of learning and mathematics directly affect the ways in which I think
about teaching mathematics to my students.

I hold the educational value that all children can learn regardless of current level or
ability. I also hold the educational value that children ought to be able to transfer problem
solving skills to other areas of mathematics, and to life in and outside of school. I attempt to lead
students to see the thinking used in mathematics problem solving the same in writing, reading,
and behavior. I am committed to relevancy of curriculum. I believe that mathematical problem
solving and mathematical reasoning fit into the larger context of schooling and society by
providing children with critical lifelong learning skills that can be transferred and used in all
aspects of their lives.

The historical context of mathematics teaching in our country suggests a teacher-centered
approach of teaching whole group and assigning problems based upon that passive way of
teaching. The teacher-centered approach provided the instruction I needed, when I was an
elementary student. However, it is not relevant in my classroom and it does not work for my
students. The historical context of teaching is changing with No Child Left Behind (NCLB) and
high stakes testing. Many students are struggling with mathematics and the traditional, whole-
class instructional method is still being used. I came to believe in the importance of changing
how I taught mathematics to children out of my own frustration with knowing and not knowing
what to do to solve a problem, while not necessarily knowing whether what I was doing was
working. During the past 20 years reading instruction has shifted from whole class instruction,
whereas this shift has not occurred in math. A different way of approaching problem solving in my classroom is the basis for my action research project.

In order to make changes in my classroom, I reviewed the current copy of the National Council of Teachers of Mathematics (NCTM) standards (2000) to use as a legitimate starting point. The problem of practice of mathematical strategies used to solve story problems and the use of expository writing as reasoning fit into several areas of NCTM. First, in the overarching principles: curriculum and teaching are the two areas where I believe this problem fits. In the current curriculum practice there is much emphasis upon the need for problem solving and the use of strategies, but it seems like the local standards, testing, other teachers, and building administrators place a huge emphasis on the rote skills of everything else while expecting problem solving to be compartmentalized into what is being done. Many teachers spend time on the other skills in math because students will need to know them at mastery to perform well on story problems. Under the process standards, problem solving, reasoning and proof, communication, and representation are all used in the expository writing process.

It seems that time would foster the use of all of these processes together in order to work “smarter not harder” from the perspective of teachers and students. Problem solving is changing at the state and district level. Under the old district content standards, problem solving was its own standard and had its own Criterion Referenced Test (CRT) in isolation. Now my district has adopted the state standards (Oct. 2009), which are a direct reflection of NCTM (2000). Under the new standards, problem solving is not a separate standard; it is an overarching process that is to be integrated throughout the four main standards. In reality teachers say they teach problem solving, and I agree they do; however, it has to be more than teaching a few memorized steps, so that students feel a little pain and frustration, so they really experience problem solving.
**Literature Review**

The common themes from the literature were: strategies, reasoning, and proof; mathematical communication through writing; and problem solving as a process oriented approach. The primary basis of my own research project involved examining individual student thinking, problem-solving strategies, and written communication. These themes are relevant to my research because the themes directly impacted my own research project, my school, and my students. I reviewed research from the United States, Canada, Spain, Australia, and Germany. Finding research from various spans of the globe was not my intent as I launched my literature review search. I stumbled upon these articles in my article search; however, I chose the articles due to their relevance to my own research. Reviewing research from many different countries impacts my thinking and belief that mathematical problem solving is not only a problem in the United States, but around the world as well. All children need to be challenged to think mathematically at increasingly higher levels and this appears to be a universal problem. The research suggests that culture, socioeconomic status, and intellectual ability are not factors that hinder learning how to solve mathematical story problems. All children are capable of learning new strategies to improve problem solving.

**Strategies, Reasoning and Proof**

When working on and completing story problems, many learners are able to arrive at an answer. However, ask any given student to explain how he or she got the correct answer, or what the given student did to find a solution, more than likely a blank face riddled with confusion will stare at the questioner. In the last two years as a learner in the Math in the Middle program, I have begun to realize the necessity of proving a solution involving explaining my strategies and reasoning for my answer. Being able to explain what was done and why it was done is a very
difficult and often a cumbersome task, but it is through many struggles that my own thinking has
been challenged and improved. Being challenged to write about mathematics, I believe has
changed my own skills, abilities, and perceptions.

Five of the articles I reviewed contained the same themes involving strategies, reasoning,
and proof. The articles are from the last decade, from Australia, Spain, the United States, and
Germany. The research from each study is summarized below.

Lowrie and Kay (2001) studied 112 sixth-grade students in an Australian primary school
in a large metropolitan area over a three-year period. Lowrie served as the regular classroom
teacher and Kay as the lead researcher. Students were each required to solve 20 mathematical
problems and to identify the method or approach used to complete the task. The results indicate
that students typically used visual methods to solve difficult or novel problems, as opposed to
non-visual strategies that were used in less difficult situations. The Mathematical Processing
Instrument (MPI) was used to assess children’s preferences for solving problems in either a
visual or non-visual way. The study used assessments, questionnaires, and interviews. The
results of this study suggest that task difficulty has a major influence on the way students
represent mathematics problems. Of the 20 questions asked, 10 were considered to be easy
questions and 10 were considered more difficult. The students generally answered correctly more
of the easy questions than the difficult questions.

Jimenez Gonzalez and Garcia Espinel (2002) examined the differences in strategies used
by various students with learning disabilities, poor performance, and typical achievement
students. For this study a sample of 148 Spanish children were obtained for the study from the
ages of 7 to 9. The children came from urban zones and from average socioeconomic
backgrounds from several state schools in Spain. Students were interviewed and asked to solve
40 word problems and four practical problems. The Intelligence Quotient (IQ) achievement discrepancy does not seem to be a relevant criterion for differentiating between students’ mathematics performance. Both Jimenez Gonzalez and Garcia Espinel are professors at the University of La Laguna in the Canary Islands in Spain.

Pape (2004) performed an in-depth analysis of sixth- and seventh-grade students’ problem-solving behaviors that were videotaped. The main goal of the study was to develop a rich description of the behaviors that middle school children exhibit as they solve word problems encountered in schools and on standardized tests. These students were from three public schools: one school in a large Northeastern city with 106 participants where the majority was predominately white, and two schools in a large Midwestern urban area with 58 participants and the majority of students were white. Special Education students and English as Second Language (ESL) students were excluded from the study. Data from 98 students of the three schools were analyzed. Students were asked to solve mathematics word problems, eight of which were two-step problems. While completing the problems, participants were video-taped in a 45-minute session and asked to think aloud. Findings in this study noted students changed the problem into mental mode, to accurately represent the problem. Students’ individual knowledge and behaviors are the resulting representation and forms the basis for a solution path.

Heinze (2005) studied gifted children in the second to fourth grades in Germany. These students were part of an ongoing action research project within a university-based program. The problem-solving strategies were observed from students as they worked on combinatorial problems, unsolvable puzzles, and sum tasks on series of natural numbers. Findings are that students are able to: recognize patterns and formal structures; able to transfer recognized mathematical structures; reverse operations and processes; use flexible mental processes; change
the representation of the problem; and possess mathematical sensitivity, creativity, and memory. Through these findings, it is believed that gifted children use a series of specific strategies to solve mathematical problems.

Alibali, Phillips, and Fischer (2009) of the Department of Psychology at the University of Wisconsin, Madison, looked at 91 third- and fourth-grade students. Participants were recruited from public and parochial schools in a mid-sized city in the Midwestern United States. Each child participated individually in an experimental session lasting approximately 30 minutes. Focus in these sessions was on equivalence problems. Students were given two pre-tests, a strategy lesson, and two post-tests. The final test was a transfer test. Over time and with development children change and shift their use of incorrect and inefficient strategies to correct or more efficient strategies. These students were asked to solve mathematical equivalence problems and completed a representation assessment in which they briefly viewed similar problems and either reconstructed each problem or identified it in a set of alternatives. Experimental groups then received a lesson about one or both of two solution strategies. A control group received no instruction. All students completed post-tests of representation and problem solving. Children taught the strategies improved their representations. Results indicate that learning new strategies is one source of changes in problem representation. In this study, children who received a lesson about a new strategy improved their problem representations. Thus it is believed, direct instruction about strategies can lead to changes in problem representation. This only held true for the equalize strategy, not the add-on strategy. Some strategies appear to be “better” than others at promoting accurate representation.

In these five studies the participants range from second to seventh graders. Each of the studies had approximately 100 participants (the smallest study had 98 participants, the largest
study had 148 participants, and one study did not specify). All of the research focused on how students solved problems. The common assessment tools were observation and student interviews. Assessments were used in a couple of the studies, and one study used questionnaires. In each of the five research projects, students were either asked to write solutions to the problems or to orally communicate them through “think aloud.” The core to all of the research was noticing problem-solving behaviors, strategies, and representation. The latest version of the NCTM “Problems of Practice” states that students must learn with understanding building new knowledge from experience and prior knowledge. It then makes sense that the best way students learn is through active explanation of their own reasoning and proof. The only way students can reason and prove is through engagement and participation of mathematical story problems, as opposed to only rote computation.

In my research project, a means of data collection centers on students writing in a math journal to record their own representations, strategies, and understanding so anyone who looks at their work would be able to understand what is being done. Students are assessed using a variety of rubrics as part of the formative process as a means to increase students’ own awareness of what constitutes clear explanations. Students were also interviewed as the second part of triangulation and asked to solve several word problems and to explain their process aloud as they think/do them. Finally my students worked in peer groups in pairs and triads to help strengthen their representation and understanding.

Mathematical Communication through Writing

Writing in mathematics seems such a novel idea. Most elementary teachers focus upon writing as a component of language arts solely due to the formal undergraduate training process; many attempt to stretch the writing process into science and social studies. However, not much is
happening at the elementary level in mathematics. Earlier in the school year, when I asked my students to explain to me, through writing, how they arrived at their answer, I got a list of procedural computation. Many students in my current classroom appear to have never been required to explain their thinking through writing. New content standards and expectations are documented in Nebraska, and teachers are expected to assess students’ knowledge and skill through oral and written communication in mathematics. A major goal of my action plan is to improve students’ individual thinking and mathematics through writing.

Three of the articles I reviewed fall into the area of mathematical communication through writing. The articles are from 2000 to 2005, from Canada, the United States, and South Africa. The research is summarized below.

Chapman (2002) performed a longitudinal case study of one child’s writing from kindergarten through third grade across different curriculum contexts with a focus on writing in mathematics, social studies, science, and music. The case study follows a young Canadian boy in an urban school district in British Columbia from a working to middle-class neighborhood. The boy’s mother collected and compiled all the written work that he produced in his primary years. Chapman took the 434 pieces of writings/drawings and sorted them into curriculum contexts, sequenced by date, and transcribed into standard spelling. A frequency distribution for each curriculum areas was created. The results from this study show the focal content-area writing began in grade one and were focused on exposition, progressing from simple lists and labels to multi-paragraph reports. The educational significance of the case study derives from the use of naturalistic data in curriculum contexts over a period of four years. Through examining the writing, Chapman, formulated two conclusions: one, the major purpose for writing is to promote learning and second, writing is to demonstrate learning.
Lim and Pugalee (2004) conducted action research in a grade 10 applied mathematics class to determine the effects of journal writing on students’ ability to learn mathematics. This study was conducted from February 2004 to June 2004, and explored the dual connection between learning mathematics and communication through journal writing. Journal entries reveal that students’ written expression improved and they were able to consolidate their learning through reflective writing. Lim conducted the action research in his classroom and Pugalee served as a university mentor through ongoing collaboration. Students’ attention to language is an important component in developing conceptual understanding of mathematics. This study suggests that formative feedback can improve student achievement.

Kemmis and McTaggart’s (1988) iterative model used plan, act, observe, and reflect was the basis for the problem solving and the journal writing. Students were provided with a 32-page hole-punched notebook and were required to journal the last 10 minutes of class several times a week. The written work was read and students were provided with feedback to improve understanding and communication. The journal was not counted toward a letter grade. Written products were scored using a 12-point rubric generated by the authors focusing on clear explanations, use of mathematical language, and algorithms that demonstrate computational proficiency. Lim is a Ph.D. student in the faculty of education at York University. His research focuses on classroom-based assessments; in particular, the role of written communication in the teaching and learning of mathematics. Pugalee is an Associate Professor of Education at the University of North Carolina-Charlotte where he coordinates the Ph.D. program in Curriculum and Instruction. His interests are in language and mathematics, particularly the role of written communication in developing mathematical understanding.
Philemon Ntenza (2006) examined the forms of mathematical writing by students in grade seven in classes of six junior high schools in KwaZulu-Natal, South Africa; one teacher and his or her students were focused upon at each of the six schools. Of the schools, three were urban, one a township, and two rural. The schools were chosen with the belief that the researcher would be able to obtain empirical data to draw generalizations from rich data and information that would be useful in determining the kinds of writing prevalent in contexts. Data collection included interviews of teachers, examination of students’ written work, observation of math lessons, examination of lesson plans, and analyzing math text books. Each school was visited three times. Of the six classes examined, only one teacher gave learners a chance to write in a journal on a regular basis. Two forms of writing were observed: symbolic writing and mathematical writing. The major question that is implicitly raised by some of the findings of this work is the extent to which writing may assist teachers in determining children’s mathematical understanding of certain concepts and whether writing can improve the learning of mathematics. Ntenza suggests more time in mathematics classrooms needs to be devoted to written communication due to the fact that currently little mathematical writing is taking place.

These three research articles could not be more different. Chapman (2002) writes about a longitudinal case study of one student over a three-year period from kindergarten to third grade; while Lim and Pugalee (2004) examine one group of grade 10 students in an applied math class over a five month period; and Ntenza (2006) examines six classrooms and six teachers over an extended period of time. The fascinating fact about these very different studies is that they each provide valuable information in regards to writing within mathematics. Chapman (2002) observes how a young man develops over time in his mathematical writing from list making to multi paragraph reports. Progressing from words, to list making, and to paragraphing,
Chapman’s observations appear to be consistent with the appropriate developmental of young learners. Chapman concludes writing promotes learning, but ultimately the act of writing is a demonstration of what has been learned. Lim and Pugalee surmised that written expression of mathematical students improved over time due to descriptive, non-threatening, formative feedback. Ntenza observes two forms of writing from students: symbolic writing and mathematical writing. Ntenza further goes on to state maybe over time writing can improve students’ mathematics. If one looks at the Lim and Pugalee findings, there is a direct correlation that writing in mathematics can improve students’ written mathematics expression, thus improve their mathematics.

My action research attempts to investigate this notion that the more students write about the math they are experiencing, the more it will improve the material they are learning, resulting in demonstration of knowledge.

_Problem Solving, a Process Oriented Approach_

Research from Horn and Frey (2002) and Lubienski (2000) dates back nearly a decade and their approaches to teaching a process and/or using a specific curriculum to improve students’ problem-solving abilities appears to be limited. I believe students are able to improve due to a teacher’s knowledge of content, delivery of teaching and expectations. Good teachers teach and raise student achievement, not processes, products, or specific curriculum packages. If improving student achievement only required teaching a set of process or using a specific curriculum, then there would have been no motive to enact the No Child Left Behind (NCLB) Legislation nearly 10 years ago. For those individuals who are familiar with the Math in the Middle program, the same can be said about that program—the core to impacting student knowledge, understanding, and raising achievement is directly correlated to teacher competency
not through the use of one specific approach or curriculum. The research of the two articles that fall into this thematic umbrella are summarized below.

Lubienski (2000) studied one classroom of 30 seventh-grade students for an entire year while piloting materials within the class, and acting as a model for other teachers in the school. The study focused on students’ Socio Economic Status (SES) differences and students’ reactions to learning mathematics through problem solving. The learning of mathematical content through open and conceptualized problems was the basis of the study. Lubienski served as a researcher and as a pilot teacher. The research was conducted in a socioeconomically diverse school in a medium sized Midwestern city, where 84 percent of the students were Caucasian. The school was the site for a pilot study for the Connected Mathematics Project (CMP) and students had used the materials for a year prior to the study. Interviews, surveys, student work, homework, teaching-journal entries, and daily audio recordings were part of the data collection. The belief that the CMP Curriculum was geared more toward the middle SES students as opposed to upper or lower SES students’ yielded data showing that an achievement-differences explanation is incomplete. Lubienski is a Professor of Curriculum and Instruction in the College of Education at the University of Illinois at Urbana-Champaign.

Horn and Frey (2002) taught 223 elementary students a heuristic strategy involving six processes: State the problem, Options to use, Links to the past, Visual aid, Execute your answer, and Do check back. The acronym, SOLVED, teaches in language specific to students in grades three, four, and five. Thirty-one third-graders, thirty-seven fourth-graders, and thirty-five fifth-graders were taught this strategy at a school that was part of a professional development consortium in which teachers had agreed that improvement in mathematical problem-solving instruction was an important goal. Students were trained in using this six-step strategy to solve
different types of mathematical problems. Accuracy in problem solving was significantly correlated with meta-cognitive processing. The third-grade students used the SOLVED strategy more rapidly and effectively than the fourth- and fifth-grade students. This case study lends support to efforts to use a more process-oriented approach to mathematics instruction so students can tackle new problems with skill and confidence so students can represent and solve these problems. Quizzes and rubrics were used as the data collection pieces.

When comparing these two studies the lenses from which they are viewed are different, but upon further investigation, both have many similar threads tying them together. Lubienski (2000) examined the work of 37 seventh-graders while Horn and Frey (2002) looked at 223 third, fourth, and fifth graders. Both used a very systematic approach to teaching problem solving and mathematical thinking. Horn and Frey (2002) used a process oriented approach of teaching students’ a series of steps to use when tackling any and all story problems. Lubienski (2000) used a set of grant materials as a pilot project, examining students of various SES classifications to understand and evaluate the reactions of lower, middle, and upper class students. The reactions of the students yielded different results than the researcher had expected. Lubineski believed at the beginning of the study that most of the middle class students would be willing to use and like the program materials and its approach.

When thinking of my own action research, I did not plan to employ a list of tasks that students must use or a programmed way of thinking. I saw the benefit in the SOLVED study, but had my own reservations in using an approach as such. Teaching a heuristic strategy may limit the freedom, creativity, and untapped thinking potential of learners. My research attempts to focus on what specifically students do to solve a word problem and why. They were free to do what made sense to them, as long as they could explain and demonstrate to another individual
their processes and thinking. Each year I spend a tremendous amount of instructional time demonstrating, modeling, and thinking aloud the manner in which I would solve various problems. As part of this process I teach students the strategies I most often employ when solving.

**Literature Review Summary**

My classroom along with other classrooms in my building need to change when it comes to teaching students problem solving, thinking, reasoning, and proof. Upon an examination of various studies from North America, Europe, and Australia, the need for improvement is not an issue that is only affecting students in the United States. All students can learn and this is a common belief of most educators. It is a belief that I hold near and dear to my own heart. The issue is how do teachers teach and reach students to help them improve their mathematical thinking. The research clearly shows students need to be engaged in the curriculum. Students need to be doing more than a series of computational math problems; they need to be experiencing reading, writing, and thinking their way through problems that they see as relevant and beneficial to their lives. When a student is able to explain what he or she is thinking it makes it easier to teach and help others.

I teach in an urban school that has been placed on alert for corrective action as part of NCLB. The students of this research are from a population of minority students in a state that is mostly rural. Conducting my action research within my own classroom was similar to much of the research reviewed. Serving as the classroom teacher and researcher, I used rubrics, oral and written communication, interviews, and student math journals as an insight of my own teaching practices to help form deeper levels of thinking for my students.
**Purpose Statement**

The purpose of my action research project was to examine students’ use of expository writing in mathematical lessons as a means for explaining their thinking through using reasoning and proof to communicate story problem solutions. I examined students’ written work in math journals and oral work of whole-class presentations, in order to answer three research questions. First, what happens to the quality of student reasoning when I focus on building students’ repertoires of representations in math class? Second, what happens to the quality of student problem-solving solutions when I focus on building connections among multiple representations in math class? Third and finally, what happens to my teaching when I focus math class on building students’ repertoires of representations and making connections among multiple representations?

**Method**

I began my actual research on January 4, 2011, and finished on April 29, 2011. I had 19 students in my classroom. Twelve average to low-ability fourth-grade students, between the ages of 9 and 10, participated in this study. Each student was provided with a composition notebook to serve as his or her math journal for the spring semester. In the math journal students glued in story problems and worked toward a solution. As part of each story problem solution write up, the expectation was to include four parts—the story problem, all work toward a solution, explanation of what was done/why it was done, and a summative statement.

The first component of my research began on January 4 by giving each student a story problem survey (see Appendix A). The survey listed 10 statements requiring a response of one to five, one being the lowest and five being the highest. The later part of the survey consisted of
three free response questions focusing on teacher, story problem favorites, and writing in math. This was the same survey given at the end of my project on April 29, 2011.

Each week during the project, one to four story problems were given to students to complete in their math journal either alone, with a partner, or in a triad. Generally, students were given the option of how to work. Most students chose a partner to embark on their journey. Our classroom, school, and district schedule dictated how many problems students were able to tackle each week. Over the course of the study, 29 total story problems were given, and 11 of those journal entries were scored. The rubric used was based upon a 12-point scale using three overarching categories: Understanding; Strategies, Reasoning, Procedures; and Communication. The rubric was titled “Classic Exemplar Rubric” (see Appendix B) that was provided to the entire staff of my building by our Instructional Facilitator to use as an informal internal measure for math problem solving to gauge student progress for AYP. The rubric was distributed to staff in October 2010, and I decided to streamline the process for my action research project and use the same rubric. My goal was to score student math journals weekly, but that was not always possible due to snow days, district in-service, scheduled school breaks, field trips, and testing. Initially, students were going to work alone on the problem in their journals, but it worked better to allow students to work together.

The next portion of my action research was to encourage students to listen and to learn from one another. My beginning goal here was to have students work in four groups on a specified problem from their math journals they had worked individually, prepare a poster, and present their work and explain their reasoning. This too had to be changed because it was difficult to make happen. Students were uncooperative, and it took too much time. I then decided that each student would use a legal-size sheet of white paper and take a specific problem of my
choosing and show their work and include a summative statement. On the presentation poster the written explanation would be omitted. Three to five students were chosen roughly every other week to display their problem-solving poster to the class and orally explain the operations and strategies they used to obtain a solution. For the presentations, I used a simple five-point rubric (see Appendix C) obtained from Sammons’ (2010) book. I chose this rubric for its simplicity and also due to the fact that my school’s Academic Leadership Team introduced the book to the staff in August 2010. We were informed we would be participating in a yearlong book study on guided math as we incorporated portions into our individual classrooms.

The fourth component of data collection was my individual teacher journal (see Appendix D). I set up my Teacher Journal entries with three sections for each week. I wanted to see the week holistically and then focus on what happened during the week. So the first section was a list of how many days of school and events that week that affected the amount or quality of instruction (such as assemblies, field trips, testing, etc.) on a blank sheet of paper. In this section I also kept track of how many student math journal entries were done, and out of that number how many, if any were scored. The final part of this section also includes how many student story problem presentations were done that week.

The second part of my teacher journal included some initial thoughts as an elementary teacher with some commentary. I mentioned one or two specific teaching events that occurred during the week, mostly focusing on the math journals and that process, but sometimes mentioned the presentations. I laid out what happened, what I did, said, and thought and also what my students did, said, and thought. I used direct quotations whenever possible. In this part of my journal, I laid out my weekly lesson plans to help reflect upon what I had intended to teach, and what actually happened during the week in my classroom. I also used my teacher
observation journal (my own composition notebook), where I recorded my thinking, questioning, and student responses of daily teaching and student interaction. I also worked to include what I wrote on the chalkboard and chart paper as a result of direction instruction, or due to issues that occurred during work time. In this section I described in a narrative fashion using notebook paper.

Finally the third part of my teacher journal was a two-page section of reflective questions. Each week I used the same questions, but some weeks there were not any change from the previous week, or I felt that the question did not apply, so I wrote N/A, for non applicable.

The last component of my data collection included student interviews. Five of the 12 study participants were interviewed one-on-one in the back of the classroom. The same 10 questions were asked in the pre- and post-interviews (see Appendix E). The questions were to gain an understanding of students’ thoughts, feelings, and approaches to mathematics. In the 11th question, each student was asked to choose one story problem to solve individually. Upon completing the question each student discussed his or her work indicating their thinking, reasoning, operations, strategies, and whether a solution was obtained. Students were recorded on a digital recording device. As the classroom teacher and researcher, I was the only person to listen to the interviews. Each student was interviewed two times, around the beginning of the project and at the end. Therefore, a total of 10 interviews from five students were transcribed.

In order to measure changes in my teaching, I relied upon my teacher journal, student journals, presentation posters, rubric data, student interviews, and student surveys. The numerical data from the rubric for student journals and presentation posters collected was nice because it forced me to read and reflect on student work weekly, then in turn hypothesize how students responded to my teaching. It was through actual reading and observing that I became aware of
elements that were working and not working in my teaching. My teacher journal proved to be very detailed, so when looking back, I was able to have insight into what happened each week. The most telling information came from the students’ pre- and post-interviews and the pre- and post-problem-solving survey. The thoughts and opinions students had toward me, my teaching, their thinking, learning, and reflection of math gave me a glimpse into their young perspectives.

The data I collected were sorted and analyzed in several ways. The student journal and presentation poster data were taken from each master class list and typed into separate spreadsheets in Excel to tabulate the individual mean scores, class mean scores, as well as the standard deviation. The teacher journals, interviews, and surveys were read and examined for themes. Also the story problem survey results were typed into an Excel spreadsheet to tabulate each question’s pre- and post-interview mean, the difference between pre and post, and the standard deviation. From each one of the spreadsheets created, I turned it into a table and a graph and exported them to Word Documents.

**Findings**

The 2010-2011 school year was in my fifth year teaching in my elementary school and my 10th in the profession. My elementary is a diverse elementary school with a student population that includes African American, Hispanic, Asian, Native American, and Caucasian students. Most students come from poverty and roughly 80 percent of the student population qualifies for free or reduced lunch. The school gets its name from a Native American word that refers to the “Great Spirit,” who was the provider of all things needed for a happy life, including land, rain, and sunlight. Currently, the school serves approximately 330 students, from pre-kindergarten through the sixth grade. As an Academy School, it offers small class sizes of approximately 15 students in kindergarten through grade three, and approximately 20 students in
grades four through six. In 1993, it was designated as the first school in our state to become a
school-wide Title I building by the Federal Government. This designation resulted in additional
financial support for all instructional areas to help aid in student achievement. Knowing the
background of my school and the students I teach helps to frame a small perspective into the
action research and data collection process.

Even though my action research began in January 2011, much of the foundation was laid
much earlier. In July of 2010, I purchased a Mathematics e-book from Evan-Moor, so I was able
to project each day’s problems from my LCD projector for all students to see. In August at the
onset of the school year and during the fall of 2010 I used these problems with my students
in preparation for the work that lay ahead with my action research project.

Each day as part of our bell work routine, while I took attendance and lunch count, my
students worked to solve five mathematics problems. My students each had a 70-page spiral red
notebook that they use for their math bell work problems. Students had approximately 10
minutes to work the problems before announcements began. When the schools announcements
were broadcasted on the TV system, the LCD projector was turned off. Then while I sorted
through homework folders, homework, and reading logs, students worked on their handwriting
assignment for approximately 10 minutes if they had their five math problems done; if not they
needed to complete the math first.

It was at this point I called my class up front to the carpet area where we were then able
to work through each problem, discuss the operations used, identify the strategies used, and why
each was used. When students worked alone prior to coming up on the floor they use a pencil.
However, when they arrived up on the floor they had their notebooks and a red correcting pen.
They were to change or fix anything they had wrong, and if they did not do a problem or get
done, they copied from the board in red pen. This red pen had a two-fold purpose. One it was for them to be aware of how they were working independently at a steady pace and if their work was correct, and two, it was a way for me to glance at notebooks and perform a quick assessment of their work pace.

Of the five mathematics problems each day, they were ranked in order from easiest to hardest. The first two problems were generally computation; the next two were skills review with patterning, geometry, measurement, or algebra. Finally, the last problem was always a story problem. All year long, once students sat down at their tables to get ready for bell work, I took a minute or two to read each problem aloud and provided some clues to begin their thinking so they can work independently.

Once students were up on the floor, as we went through the five problems, it became an opportunity for review, interactive thinking, interactive writing, and often direct modeling. It was during this daily routine that I began to introduce my students to the four operations and 10 strategies to help focus their thinking. It was through conversation and direct modeling that most students became able to identify the operations and strategies they used when working on story problems in their math journals, whether it was alone or with a partner.

The photograph below shows an explicit strategy allowing students an opportunity to a complete a story problem during bell work in early Fall of 2010. The problem that generated this work is as follows:

Igor built a pyramid with blocks. He has one block in the top row and four blocks in the next row. In the third row he has nine blocks, and in the fourth row he has sixteen blocks. If he continued this same pattern, how many blocks are in the seventh row.
From this initial bell work problem my students were asked to notice a pattern in the numbers. As a class this was accomplished, however students were introduced to the concept of first difference and second difference as well as the vocabulary word “constant.”

This was the explicit foundation I laid to link to my action research project. I had demonstrated and explained all year long that mathematics was the process of thinking, and through that thinking one must be able to read and communicate through oral speaking and written communication. In essence I tried to get my students to see the following metaphoric equation: Thinking = Reading = Writing = Math. They are all linked together; they are all the same thing. Our primary purpose to study and to get an education is so students are able to think, reason, and communicate throughout their lives, no matter what situation or circumstances they are placed in.

In order to decipher the data collected, I decided to look at each research question individually and draw conclusions. The class in which I conducted my action research project
was my regular self-contained class of nineteen fourth graders. Mathematics was scheduled at
the same time each day, from 10:40 – 11:40AM and most days we began on time, but often ran
over our scheduled 11:40AM cut off point due to student engagement and follow-up teaching.
When the research project began I used the first half of the math period to give the story
problem, offer guidance, and allow group work. Shorty thereafter I realized that my action
research was taking more and more of our math time and other standards were not being taught
deeply enough. I then decided to reverse the order and begin with the first 30 minutes with a
shortened regular lesson and then end with story problems and math journals.

I found it more difficult than I anticipated establishing story problem writing in math
journals for my students because I thought students would understand the process better and it
would go faster. First I expected students to copy the problem from the board or chart paper, but
this was taking up too much time. So then I provided the story problems for students to cut and
glue stick into their journals. This went faster, but the issue became the cutting. So I realized I
needed to have the problem precut and all students needed to do was glue it in their math journal.
I did not score any of the story problems the first two weeks, because routines and expectations
were established and practiced. I wanted students to feel comfortable in what they were doing
and envisioned each student working alone on the story problem followed by working in groups
for their peer presentations. I decided to switch both around, where students worked with a
partner or in a triad on the story problem and then presented the solution and thinking
individually.

When I began my research in January I wanted to have four groups of students present
the same problem, but since I made the journals collaborative, I decided to have 3-5 individual
presentations at a time. The reason for this was so students had to make a presentation poster,
and I did not want students to sit through 19 presentations of the same problem, due to the fact it is not the most effective use of instructional time. I had to rethink what I was doing. The presentation process actually worked out better due to the fact that I could choose students who had either similar work, to help guide students thinking to see patterns or I could choose students who had completely different work, to further probe thinking and understanding.

The most difficult routine implementation was to observe and question students as they worked. I asked students to explain their thinking as they worked or to tell me their reasoning as to why they chose to go the route they did. As time went on I got better at having my composition book with me and writing what I saw and heard. Students even responded politely when I would say, “Just a minute, I have to write too.”

After establishing routines and norms a typical day ran pretty smoothly. Usually students were called up to the front of the room on the carpeted area for the anticipatory set which included review of the four basic mathematical operations, singing a song with actions and orally reviewing the strategies most often used when working on story problems. Generally I listed the strategies on the board really quick to help ingrain in students’ schema for individual automaticity. I would then pass out the pre-cut story problem and read the problem aloud while students followed along. Then we would read the problem a second time together. I would then either point out a major theme of the problem or ask questions about what operations and/or strategies students thought they might use to begin their problem. After a few call and responses students were sent back to their tables to begin working. Students got out glue sticks, pencils, math journals, and erasers. Each student would glue the story problem into his or her journal, clean up supplies, and choose a partner and a location to work. Students were given the option to work with a partner of their choosing (someone with whom they could be responsible with) or
alone. Most students chose to work with a partner or a small group of three. I had a couple of students who preferred to work alone, however occasionally I would force them to pick a group. Once students chose a location to work, whether at a table or on the floor, they were expected to get to work immediately.

Many students would reread the problem together and discuss what was being asked and how they thought they should get an answer. Even though students were working together, they were required to write in their own math journal. Students were to show any and all work. If students decided the work was wrong or changed their mind, they could not erase, they needed to cross it off. I chose to have students do this to help me in my observations and scoring as well as for each student to have a record of previous work that may or may not have lead to a different way of thinking.

After students solved the problem, the next portion of their math journal was to explain what they did and why they chose to do what they did to solve the problem. As the research project went along, I told students to write their thinking in a way that a first grader would understand; this seemed to make more sense to students when I would prompt them to write more describing their thinking process. After the written description of work and explanation, students were to write a summative statement describing the problem and the answer in a sentence or two. Most students would write the summative statement before their written paragraph(s) of their reasoning.

As students worked on problems, I would circulate around the classroom and listen to conversations focusing on approaches they used to solve the problem. I made notes in my composition notebook of issues encountered, asked students what they were doing to solve a problem and why they chose the strategies they did. I worked cautiously to guide student
thinking rather than explain or give answers. I often would prompt students to think about a strategy or operation. If that did not work, I would remind students of previous problems that were similar to the one they were stuck on. This connection making process greatly aided students to think on their own. Students would finish their work; I would glance over their entries and collect them. Whenever a problem proved to be too difficult, I would pull the class back together and prompt or coach the whole group to use our time most effectively.

Here is an example of a typical day from teacher journal #12, dated the week of March 28, 2011, to April 1, 2011, where I described how I tried to help students work on written explanations in addition to solving the problem with strategies and computation. The story problem in student math journals was:

“It takes 120 days for Matt to save enough money to buy the book he wants. How many days will it take to buy 5 books?”

I presented the problem as usual to my students. I gave the problem, students glued it in, and we read the problem together aloud. I answered questions and then students chose a partner and went to work. My goal this day was to pay attention to small groups. The first group I stopped at a student said, “But Mr. Beyer, we don’t know how much the book cost, how much money did he save?” Right here, a student showed me how her thinking was different from mine. She was caught up on the cost of the book and a dollar amount. She was confused because she did not have the information she believed she needed to work the problem. I told her we are solving for number of days, not the amount of money. She said, “Ok.”

I immediately stopped everyone and went to the board because if one student is confused, other students potentially could be too. So I wrote some information on the board to help the class see the problem correctly and to guide their thinking.
This is what I wrote:

\[
\frac{\text{Days}}{120} = 1 \text{ Book} \\
\quad = 2 \text{ Books} \\
\quad = 3 \text{ Books} \\
\quad = 4 \text{ Books} \\
\quad = 5 \text{ Books}
\]

I organized what was given in the problem, so students could focus on their own operations and strategies. I may have guided too much; however, I wanted to scaffold support to a proper solution. I felt if I did not help steer them in the right path they may then solve the problem wrong and believe they solved it correctly. When students though they were done, I told them they had to come show me their journals and as they came back to me I personally told each one to: “1) Show more. 2) Explain why you solved it that way.” Below are three journal entries from this lesson.

Amelia’s\(^1\) Math Journal: 3/30/11

James’s Math Journal: 3/30/11

\(^1\) All names are pseudonyms.
Lily’s Math Journal: 3/30/11

I chose the problem more carefully than from the previous week. I felt students were able to see the problem at face value and be able to complete the problem with a partner without help from me. I wanted students to have an entry point to the problem and feel comfortable being able to solve the problem while building self-confidence. I wanted students to see the direct connection of repeated addition, multiplication, skip counting, and making a list. Overall the lesson and problem went well, but we had some stumbling blocks along the way. This is just one example of how a typical day and lesson played out during this action research project.

I wanted to know what happened to the quality of student reasoning when I focused on building students’ repertoires of representations in math class. I found students were inconsistent with the quality of their reasoning over the 16 weeks. The graph below shows overall how varied students’ individual mean journal entries developed. The scores varied from 5.80 to 11.05 (see Appendix F for numerical table of data).
In students’ math journals, a total of 11 entries were scored on a 12-point rubric. The class mean fluctuated between 11.05 (Journal #8) and 5.80 (Journal #7). These results can be observed on the graph below. The trend in journal data leads me to believe that students were inconsistent with their mathematical reasoning of operations, strategies, and written explanations based upon the criteria of the scoring rubric used.
It is possible the difficulty of the problems contributed to this fluctuation as well. If I had rated the difficulty of the problems given I could have used those ratings to weight the scores for each week. I maybe would have seen growth or at least less fluctuation. I observed this when comparing several students work at varying times. Below are three students work from two different dates. First are two of Grace’s journal entries:

Grace’s Math Journal: 3/16/11, Score 5/12   Grace’s Math Journal: 4/25/11, Score 10/12

Grace’s overall math journal mean during the study was 9.2/12. Her journal scores were inconsistent, with her highest scores at the beginning and end of the study and her lowest scores in the middle. During the week 3/16 I noted in teacher journal #7, “This week was amazing because we talked, made and wrote so much together and individually, that I could really see the effort and thought of student reasoning. It is getting better.” However, my reflection does not reflect Grace’s score.
Next are two of Gavin’s journal entries:

Gavin’s Math Journal: 2/7/11, Score 12/12

Gavin’s Math Journal: 3/16/11, Score 6/12

Gavin’s overall math journal mean during the study was 9.09/12. His journal scores were inconsistent with the trend of his individual data increasing then decreasing from week to week. His highest scores were on journal entry #3, #4, and #8, but his lowest score was on journal entry #2.

Here are two of Jayden’s journal entries:
Jayden’s Math Journal: 3-30-11, Score 12/12

It takes 120 days for a farmer to save enough money to buy a book he wants. How many days will it take to buy five books?

\[
\begin{align*}
120 &= \frac{120}{2} = 60 \\
120 &= \frac{120}{3} = 40 \\
120 &= \frac{120}{5} = 24 \\
120 &= 12 \\
\frac{120 \times \frac{12}{6}}{12} &= \frac{120}{6} \\
600 &= \frac{120 \times 6}{6} \\
12 &= \frac{120 \times 12}{600} \\
\end{align*}
\]

What we did was we add 120 times to get our answer. We \(120 \times \frac{12}{6} \) to get 600 days. It will take Matt 600 days to save enough money to buy the 5 books.

Jayden’s Math Journal: 4-25-11, Score 5/12

Marissa has 32 marbles. She gives 12 to John. She takes 5 from Sally. She gives 9 to Mark. John gives her 10. Which number sentence describes what has happened?

\[
\begin{align*}
\text{Marissa} &\quad \text{John} \\
32 &\quad -12 \\
-5 &\quad +9 \\
+10 &\quad = x \\
\text{Marissa} &\quad x \\
\end{align*}
\]

She gives 12 to John.
She gives 9 to Mark.
She gives 3 to Sally.

\[
\begin{align*}
\text{Marissa} &\quad \text{John} \\
32 &\quad -12 \\
-5 &\quad +9 \\
+10 &\quad = x \\
\text{Marissa} &\quad x \\
\end{align*}
\]

Jayden’s overall math journal mean during the study was 6.6/12. His journal scores were inconsistent with the trend of his individual data decreasing then increasing from week to week. His highest scores were on journal entry #5 and #7, but his lowest score was on journal entry #2. During the week 4/25 as noted in teacher journal #16, “I did not focus this week and the student quality suffered. Not allowing students to work with a partner really caused some poor work.” Therefore, my reflection does reflect Gavin’s score.

When scoring student presentations using a 5-point rubric, the mean fluctuated also. I found students were inconsistent with the quality of their oral reasoning over the 16 weeks. The graph below shows each student’s mean score for their presentations over the duration of the research project. The highest student’s score was 5/5 and the lowest score was 0/5 (see Appendix G for a table of numerical data).
In students’ problem presentations, a total of 10 presentations were scored. The class mean fluctuated from 5.00 (week 1) to 2.00 (week 3) as can be seen in the table below (see Appendix H for a table of numerical data).

This trend in data leads me to believe that students were inconsistent with their mathematical reasoning, strategies, and oral communication based upon the criteria of the scoring rubric used. The numerical results of students’ problem solving presentations can be
open for interpretation and the data are inconsistent. The presentation data may not be easily averaged due to choosing only three to five students each week for presentations; the number of times each presented differed, and there was no set rotation of students. In retrospect, I should have worked out a systematic rotation with the exact number of presentations each week. This would have made the results here more reliable.

Finally, my teacher journal also reflects my observations of student reasoning. The beginning of the project I noted in teacher journal #1, “Students were able to reason well orally…” My attitude and observation stays the same as noted in teacher journal #4, “The quality of student reasoning continues to improve, but it’s far from perfect.” Then it seems like the quality was a roller coaster as noted in teacher journal #6, “This week the quality of student reasoning went down due to the fact that I gave a much more difficult problem…” and in teacher journal #12, “The quality of student reasoning was much better this week than last week. Students used repeated addition and multiplication, made lists and tables to solve and explain their explanations were great.” Then again it seems as though students take a backwards slide as reflected in teacher journal #14, “Two weeks ago the average journal entry score went up, this week it went down. The math reasoning is good, but the writing explanation could be better.”

Through examination of these three sources of data: teacher journal, student presentations, and student math journals the pattern of student inconsistency with the quality of reasoning is evident. For several reasons, I suspect the trends in data can be hypothesized. Each student was at a different place developmentally especially when it came to the use of operations and strategies. The story problems I give did not have a common theme among them; they were sometimes different in nature. Students may not have had enough schemas to understand,
connect, or enter the problem. Ultimately, students need more opportunities for modeling and practice.

The second question I sought to answer was what happens to the quality of student problem solving solutions when I focus on building connections among multiple representations in math class? Again the data suggests that students are inconsistent with the quality of their problem solving solutions. For the same reasons discussed prior about students’ inconsistency of quality of reasoning, the same can be said here for the quality of student problem-solving solutions.

Upon reviewing the data one can argue the data supports differences in the quality of students’ problem solving solutions with multiple representations through the examination of math journals and problem presentations. Observe this in comparing several students work at varying times. Below are three students work from two different dates.

Look at two journal entries for Jacob first:

Jacob’s Math Journal: 1/20/11, Score 9/12

For breakfast in the morning, you may choose among three different cereals: corn flakes, oatmeal, or wheat chunks. You might also choose a juice, either apple juice or orange juice. What are all the different breakfast combinations that you could have if you had one cereal and one juice?

Jacob’s Math Journal: 4/18/11, Score 12/12

18. Shane has $23.00. He wants to buy a train set for $15.30, a hat for $5.70, and a whistle for $1.35. Does he have enough money?
Jacobs’s overall math journal mean during the study was 9.89/12. His journal scores were inconsistent with his highest scores at journal entry #6, #9, & #10 and his lowest score on journal entry #2. During the week 4/18 I noted in teacher journal #10, “The ‘math’ portion was great” and my reflection does reflect Jacob’s score.

Next look at two of Zoe’s journal entries:

Zoe’s Math Journal: 3/8/11, Score 7/12

Zoe’s Math Journal: 4/13/11, Score 8/12

Zoe’s overall math journal mean during the study was 6.91/12. Her journal scores were inconsistent with the trend of her individual data increasing then decreasing from week to week. Her highest scores were on journal entry # 8 and #10, but her lowest score was on journal entry #7. During the week 4/13 as noted in teacher journal #14, “Two weeks ago the average journal
score went up, this week it went down. The math reasoning is good, but the writing could be better.” My reflection does reflect Zoe’s score.

Third, examine two journal entries from Ethan:

Ethan’s Math Journal: 1-20-11, Score 5/12
For breakfast in the morning, you may choose among three different cereals: corn flakes, oatmeal, or wheat chunks. You might also choose a juice, either apple juice or orange juice. What are all the different breakfast combinations that you could have if you have one cereal and one juice?

Ethan’s Math Journal: 4-25-11, Score 6/12
Marissa has 35 marbles. She gives 13 to John. She takes 5 from Sally. She gives 9 to Mark. John gives her 15. Which number sentence describes what has happened?

Ethan’s highest score was on journal entry #8, but his lowest score was on journal entries #1 and #9. His journal scores were inconsistent with the trend of his individual data varying from week to week. Ethan’s overall math journal mean during the study was 7/12.

Finally, my teacher journal also reflects my observations of students’ representations. At the beginning of the project I noted in teacher journal #3, “When students have more than one way to solve and think about the problems it increases their ability, success, and confidence.” My attitude and observation stays the same as noted in teacher journal #4, “Student problem solving solutions improve when given the opportunity to solve various ways, especially from peers.”
Then it seems like the quality falls as noted in teacher journal #6, “This week the quality of student reasoning went down due to the fact that I gave a much more difficult problem…” and said in teacher journal #12, “Using multiple representations helps lead to deeper reasoning. This week the overall average score was 11.05/12, the best so far and 2 times the average last week.”

Again, through examination of these three sources of data: teacher journal, student presentations, and student math journals the pattern of student inconsistency with the quality of problem solving solutions with multiple representations is evident. Students may solve the computation correctly, but have a more difficult time with written expression. Students’ articulation may be better than their written expression abilities. Presentation scores were higher than written scores from student journals. The highest class mean for presentations was 5/5 whereas the highest class mean for writing in math journals was 11.05/12. The presentation mean is slightly higher than the math journals. Furthermore, students may not know how to solve the problem using correct computation and therefore are unable to express correctly the solution in writing. Thus, students need more opportunities for modeling and practice.

Third, I wanted to know what happens to my teaching when I focus math class on building students’ repertoires of representations and making connections among multiple representations. I discovered that my teaching became more explicit and intentional. Knowing the biggest factor of student success or failure rested on my shoulders, I began to be explicit and intentional in what I modeled for students, how I wrote, thought aloud, and used vocabulary. This is evident from the beginning of the project as noted in teacher journal #1, “When I see and hear students make connections, it makes me want to show many ways to see a situation so they have a way ‘in’ to story problem solving.” My reflection and attitude not only helped me focus in math class, but also during our daily bell work problems more intently. I tried to use the limited
time I had to my students’ advantage by using that initial time period at the beginning of the day to plant seeds through modeling for development and growth during math class. As discussed in teacher journal #5, “When I focus on making connections and multiple representations my vocabulary becomes precise, teaching becomes more animated, and I allow for more think time. I am [also] aware to articulate my thinking and then show that many different ways.”

During the week of 2/14 to 2/18/11, I gave two story problems, one on Monday and one on Tuesday, and then realized the problems I had chosen were too challenging for my students. I then spent the remaining time with my students re-teaching, modeling, and turned one problem into an activity to build deeper understanding. It then took three days to construct our model, pull it apart, and work on our write up. As reflected in teacher journal #7, “My teaching changed and got better. When I am able to see where students are and are not during a lesson… I have to think on my feet to rearrange the lesson or think overnight. This week I had to really reflect and ask myself, ‘What can I change and do better?’” It was during this week that I began Wednesday’s lesson stating, “We’re going to go back and build our math problem.” In this problem a young girl needed to determine how much wrapping paper was needed to cover a box. Students were confused and excited at the same time. Before students began their own construction of a box with the given dimensions, I changed the numbers on the original problem from decimals to whole numbers to make the problem more appropriate for the manipulatives I gave the students.

I launched into a lesson and then we reviewed 3-D shapes and their properties. I also demonstrated how the net of a geometric solid is made using a wooden block and a plastic net. Students were very engaged; I wanted them to remember and connect to previous problems from earlier in the year. As a class we constructed a box with Unifix Cubes. Students said, “Cool. Wow.” Then I passed out sheets of one-inch graph paper for students to construct the box of the
math problem in order to determine the surface area of the gift that needed to be wrapped. The overall class mean for this solution write up in math journals was 8/12, the best yet out of the four done up to this point.

After each week was over, I reflected upon my own practices in the classroom. I was able to “become much more precise and able to step back and work with small groups, see where students are struggling and ask questions to get students to think rather than showing,” as mentioned in Teacher Journal #8. The same week, the class mean for math journals climbed a little higher from the previous week to 8.32/12.

I noticed a vast difference when I moved from more whole group instruction to small group and partner work. The mean math journal score for journal entry #8 was the highest at 11.05. I state in teacher journal #14, “My teaching this week was different as I coached more, I went from group to group, and told students I wanted to see different ways to solve the problem. When I directly see what students [are doing] it makes me more focused as how to question them and guide thinking.”

Furthermore, I believe the results from the pre- and post-problem survey have a direct correlation to my teaching, how students worked with story problems, and their attitudes. Of the 10 statements on the survey, all 10 had a positive difference from pre to post as can be seen in the table below (see Appendix I for a numerical table of data).
The most surprising difference was on statement #2, “I am good at story problems.” This was the largest increase from 3.2 on the pre survey to 4.39 on the post survey. This was the only statement that had a gain greater than one (see Appendix J for a numerical table of data).

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I honestly thought that there would be some negative differences in the results from the beginning to the end of the study. I was happy and amazed because it validates the work that I did as a professional in the classroom. As the classroom teacher, I spend the time energy, and effort with focus and intention, and drive to make an impact not only on student achievement but also impact attitudes and perceptions toward the content area.

Of all of the data collected, I found the student interviews to be the most interesting yet intriguing. Out of the 12 students who returned signed parent consent, five students were interviewed. It was telling what students thought about story problems and how they went about solving them individually. When asked, “Do you like doing story problem presentations?” the
When the same question was asked during the post-interview the general response was an outstanding, “Yes.” When students were asked, “What does it look like when you explain story problem answers?” the pre-interview responses were “Pictures, writing, and graphs.” The post-interview response was “work and writing.” I found this interesting and meaningful. Students’ perceptions changed to include a view point of writing in the content of math. When students were asked, “What are the benefits of explaining your story problem answers?” the pre- and post-interviews yielded the same general result of “helping others to think and see strategies.”

However, when asked “What math strategies to you use the most and least in your explanations?” in both the pre- and post-interviews, there was a discrepancy between what a strategy was and what an operation was. Many students intertwined both strategies and operations and explained as if they were one and the same. This was quite disappointing to me that even after so much work, practice and singing, students still struggled to identify a difference in the two. It makes me question what I could go back and change. It led me to believe that in order for students to identify and use a strategy or an operation it requires more than just mere memorization of vocabulary; there needs to be context applied to each and much exposure over time is needed.

When asked, “What makes story problems easy and difficult for you?” in both pre- and post-interviews the responses were mixed. Some students identified something that was easy yet another student identified that as something of a challenge. It was not surprising to me because all children are different and what one perceives as easy another may view as hard based upon prior knowledge and experience. So the inconsistency of similar answers here is justifiable. The interview question, “Did you enjoy working on story problems before this school year?” was the
most surprising because students answered with a resounding, “No.” Then when asked, “Has your attitude about working story problems changed during the school year?” student during the pre- and post-interview answered, “Yes it got easier. Yes, it got better.” On student in particular replied, “It got better. At first I didn’t like story problems, and then it changed.”

Two further findings through the interviews were that when given the opportunity to offer me advice on how to help them understand better, I generally got no response. Also, students stated they enjoyed and preferred working with a partner. As the course of the semester went on, I observed this more and more. Students became more comfortable working with others and confident in their mathematical abilities. The final part of the interview process that was the most surprising was when students worked on a story problem they chose individually, some improved in their computation, reasoning, and proof, while others did not. This once again ties back into the theme of inconsistency of students over time with regard to story problem solving.

Through examination of these three sources of data: teacher journal, student surveys, and student interviews, the pattern of explicit and intention teaching is evident. When I am focused on reasoning, solutions, and written expression, I am more apt to intentionally think through an entire lesson, step by step with what I see the desired outcome to be. As a teacher, when other classroom issues and deadlines are present, internal conflict causes me to lose focus and my teaching is not as explicit or intentional.

**Conclusions**

Expository writing in mathematics did appear to have an impact on students in terms of explaining their thinking using reasoning and proof to communicate a story problem solution. The question remains how much an impact this action research had on students’ thinking, writing, and problem-solving abilities. If one only looks at the quantitative data presented here,
the answer to the initial purpose statement of the project may differ. As a classroom teacher I know that students are far more than the sum or mean of their academic scores. It is through the qualitative data as well, that as a teacher and a researcher I witnessed change in each one of my students. Finally, this action research project may be replicated in any classroom with the results yielding either similar or drastically different findings. Further research needs to be done in elementary classrooms where expository writing is the focal point using reasoning and proof to communicate story problem solutions.

Lowrie and Kay (2001) indicated that students typically used visual methods to solve difficult or novel problems, as opposed to non-visual strategies that we used in less difficult situations. In my research I found students also typically used multiple visual methods, such as drawing a picture or making a table, to aid in solving difficult or easy problems. Pape’s (2004) in-depth analysis of students’ problem-solving behaviors noted students changed the problem into mental mode to accurately represent. I found the complete opposite of my students. As fourth graders, students’ worked primarily at the concrete operational stage when solving most story problems. Alibai, Phillips, and Fischer (2009) looked at 91 third- and fourth-grade students. In this study, children who received a lesson about a new strategy improved their problem representations. I also found this to be true. Most students in my classroom were unable to identify a mathematical strategy at the beginning of my research. Upon completion of the study, most students were able to use as well as identify the strategy or strategies used to solve a story problem. Over the course of my project, I noticed a pattern with my students and their story problem solutions in their math journals. Students demonstrated a high use and understanding of drawing pictures, making lists, and creating tables as a means to a solution, often including a
column titled “cumulative total.” Specific instruction including multiple strategies and their uses appeared to influence students work and solutions.

**Implications**

During the next school year, 2011-2012, I will most definitely be using math journals, problem presentations, and student surveys to teach mathematics and guide students in problem solving. Students appreciated working together and were pleasant, cooperative, and willing to help and learn from one another. In my classroom I was strict and disciplined with my students, yet soft enough to model and teach students how to get along and coach another learner without just giving answers. I plan to begin the process of math journals in October rather than in January. I believe that students need more opportunities to see expository writing in math modeled and students need repeated practice.

As part of my own teacher leadership, I intend to share my action research project with my principal and instructional facilitator as a way to encourage change among perceptions and teaching. Upon their approval I would then share my project and findings with my entire staff. This would allow a dialogue to take place to encourage others to begin the process of exploring expository writing as a means of communication for learning and of learning through mathematics story problems. Finally, I do plan to informally engage in professional dialogue with colleagues who are interested in learning more.
References


Appendix A

Story Problem Survey

Please give your honest response to each statement, 1 being low and 5 being high.

1. I like doing story problems.  
2. I am good at story problems.  
3. I am able to show my work.  
4. I am able to explain my thinking.  
5. I like to share my solutions.  
6. I like to share my thinking.  
7. I understand story problems.  
8. I like writing to explain my solution.  
9. Writing helps me understand better.  
10. Listening to others’ helps me think better.

Complete the following statements.

11. My teacher can help me understand story problems better by:

12. My favorite part of work on story problems:

13. Writing in math has helped me by:
## Appendix B

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<td><strong>Understanding</strong></td>
<td>There is no solution, or the solution has no relationship to the task. Inappropriate concepts are applied and/or procedures are used.</td>
<td>The solution is not complete but some, but not all of the mathematical components are presented in the task.</td>
<td>The solution shows that the student has a broad understanding of the problem and includes all of the mathematical components presented in the task.</td>
<td>The solution shows a deep understanding of the problem and includes the ability to identify the information necessary for the solution.</td>
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<td><strong>Strategies, Reasoning, Procedures</strong></td>
<td>No evidence of a strategy or procedure is used.</td>
<td>Uses a strategy that is partially useful, but not complete.</td>
<td>Uses a strategy that leads to a solution of the problem.</td>
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<td><strong>Communication</strong></td>
<td>There is no explanation of the solution, the explanation cannot be understood or it is unrelated to the problem.</td>
<td>Explanation is not clear or is expressed in terms of mathematical terminology and notation inappropriate use of mathematical terminology and notation.</td>
<td>There is an incomplete explanation, it may not be clearly presented.</td>
<td>There is an appropriate use of accurate mathematical representation, and notation appropriate of the problem.</td>
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| **Exemplars Rubric** | There is no evidence of mathematical reasoning or mathematical proof. | Some parts may be correct, but the correct answer is not achieved. | Mathematical procedures used. | Makes mathematically relevant observations and/or connections.

We refer the reader to Exemplars, 2005.
### Problem-Solving Checklist

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<td>5. Problem solving was extended through recognition of patterns, relationships, or connections to other areas of mathematics or to real-life applications.</td>
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Name: ___________________________ Date: _______________

Task: ____________________________

Assessed by: ____ Self  ____ Peer  ____ Teacher
Appendix D

Teacher Personal Journal

Reflection Questions

1. How does each of the two incidents I wrote about relate to my research question(s)?
   
   • What happens to the quality of student reasoning when I focus on building students’ repertoires of representations in math class?

   • What happens to the quality of student problem solving solutions when I focus on building connections among multiple representations in math class?

   • What happens to my teaching when I focus math class on building students’ repertoires of representations and making connections among multiple representations?

2. What changes have I seen in my students this week?

3. What surprised me this week, related to my problem of practice?

4. What went really well this week, related to my problem of practice?

5. What did I learn this week that will inform my teaching and/or journaling next week?

6. What tensions did I feel this week between my dual role as teacher and researcher?
Appendix E

**Student Interview Questions**

Student interviews will be focused on a subset of these questions.

1. Do you like doing problem presentations? Why or why not?
2. What does it look like when you explain story problem answers?
3. What are the benefits of explaining your story problem answers, if any?
4. What math strategies do you use the most/least in your explanations?
5. What do you like best/least about story problems?
6. What makes story problems easy and/or difficult for you?
7. Did you enjoy working story problems before this school year? Why or why not?
8. Has your attitude about working story problems changed during this school year?
9. How are story problems connected to other areas of math?
10. Is there anything else I should know about you to better understand how you solve story problems?
11. I would like you to work one of these problems. Once you have decided which one, tell aloud whatever it is you are thinking as you solve the problem. I especially want to hear you talk about how you decide what to do to solve the problem. Mention any strategies you may use to solve the problem.

   a. Dan uses 6 sheets of lined paper each day at school. He has 168 sheets of paper left over from last year. How many days will this paper last?
   b. Jose has a garden shop. One customer wants to buy 63 Lupines. There are 7 Lupines in a pack. How many packs should Jose sell to his customer?
   c. Ms. Holloway is having a classroom party. She asked her 27 students to help plan it. Ms. Holloway wants to give each student 15 jelly beans. How many jelly beans should she buy?
   d. Workers are harvesting the carrots in a field. Each of the 19 workers picks 11 pounds of carrots. About how many pounds of carrots did they harvest in all?
   e. Sally loves pancakes. She ate 10 silver dollar-sized pancakes on Monday, 9 on Tuesday, and 8 on Wednesday, and so on through Sunday. How many pancakes did she eat in all from Monday through Sunday?
## Appendix F

### Student Math Journals: Summative Data View

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### Appendix G

## Story Problem Presentations: Individual Data Results

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### Story Problem Presentation Results

#### Whole Class Data View

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<th>Date</th>
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<td>2/8/2011</td>
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## Problem Solving Survey Results

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<th>Post Mean</th>
<th>Post Std. Deviation</th>
<th>Pre/Post Mean Difference</th>
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\( n = 19 \) (the number of students in my class)
## Story Problem Survey Results

Please give your honest response to each statement, 1 being low and 5 being high.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>PRE</th>
<th>Std. Dev.</th>
<th>POST</th>
<th>Std. Dev.</th>
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<tr>
<td>1</td>
<td>I like doing story problems.</td>
<td>3.40</td>
<td>1.12</td>
<td>4.11</td>
<td>1.22</td>
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<td>2</td>
<td>I am good at story problems.</td>
<td>3.20</td>
<td>1.03</td>
<td>4.39</td>
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<td>3</td>
<td>I am able to show my work.</td>
<td>3.90</td>
<td>1.09</td>
<td>4.39</td>
<td>0.92</td>
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<tr>
<td>4</td>
<td>I am able to explain my thinking.</td>
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<td>1.26</td>
<td>4.11</td>
<td>0.83</td>
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<tr>
<td>5</td>
<td>I like to share my solutions.</td>
<td>3.20</td>
<td>1.39</td>
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<td>1.58</td>
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<tr>
<td>6</td>
<td>I like to share my thinking.</td>
<td>3.90</td>
<td>1.09</td>
<td>4.17</td>
<td>1.42</td>
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<tr>
<td>7</td>
<td>I understand story problems.</td>
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<td>1.11</td>
<td>3.94</td>
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<td>8</td>
<td>I like writing to explain my solution.</td>
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<td>1.21</td>
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<td>9</td>
<td>Writing helps me understand better.</td>
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<td>1.22</td>
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<td>Listening to others’ helps me think better.</td>
<td>3.90</td>
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</table>

\[ n = 19 \text{ (the number of students in my class)} \]