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Marcia J. Smith  
*Bartlett, NE*

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**Written Solutions of Mathematical Word Problems**

**Marcia J. Smith  
Bartlett, NE**

**Math in the Middle Institute Partnership  
Action Research Project Report**

**In partial fulfillment of the MAT Degree  
Department of Mathematics  
University of Nebraska-Lincoln  
June 2008**

## **Written Solutions of Mathematical Word Problems**

### **Abstract**

In this action research study of my classroom of ten ninth grade algebra students, I investigated how my students expressed written solutions of mathematical word problems. I discovered that my students writing and performance improved as they experienced different strategies to attack problem solving. These experiences helped improve the confidence of my students in their problem solving skills and in their mathematical writing. I also discovered that my teaching style changed, as my students took on more responsibility for their learning. As a result of this research, I plan to implement problem solving activities in all my classrooms next year. I also plan to have my students develop their written communication skills by presenting their solutions to their problem solving activities in writing.

## Introduction

My action research concerns written communication with problem solving in a ninth grade algebra classroom. Students need to be able to explain in writing how they solve problems. They need to organize their thoughts, use precise mathematical language and describe the processes they used to solve a particular problem. This writing helped my students understand how they are solving the problem, identify the strategies they are using, and describe the conjectures they are making. Students need to justify their solutions. Is their answer reasonable? They need to show once they have an answer, that they can check it and determine that it will work in the given situation. They need to explain the entire process in writing, using mathematical terms, correct grammar, and punctuation. Written communication is a valuable skill in mathematics class as well as other classes.

I was interested in my students' confidence in solving problems. I had many students who struggle with problem solving. If students solve many problems as a class, in groups, and individually, would these experiences affect their confidence levels? I wanted my students to be confident. I wanted them to feel like they have many strategies to use when attacking a problem. Students need to feel that they have ideas to share with their classmates. They need to have confidence in their mathematical computations. Students should feel they have the ability to communicate in writing about their solutions.

In the past, I have required students to show their work when solving problems, but not explain how they solved the problem. For example, they showed me that they divided two numbers, but not why they chose to divide. My students sometimes verbally explain their processes to others in their groups or to the entire class, but they do not write out their explanations. This writing about problem solving was a big change for my students.

Finally, I wanted to examine how implementing this process in my classroom changed my teaching. My typical classroom involved group work following a lesson presentation. My students enjoyed working in groups, but they still looked to me for help. I provided too much support and did not let my students struggle to find their own answers. This struggle could enable my students to develop confidence and become better problem solvers. My teaching needed to change and this action research project was an excellent opportunity for me to explore a new teaching environment.

### **Problem Statement**

I believe that writing about how to solve a problem is very important. I can use a student's written explanation as a valuable tool. It enabled me to understand how my students are thinking. This written communication gave me an opportunity to evaluate student learning. I investigated not only what they are learning but also how they are learning. My class's written explanations also helped me to make instructional decisions, such as determining what concepts my students do not understand. This allowed me to identify students who need extra help and those who could use further challenging.

More importantly, writing about problem solving helped my students. They needed to improve their communication skills. Students need to be confident writers and effective communicators. They need to be able to express processes, ideas and concepts efficiently and succinctly. This communication skill is valuable not only in mathematics, but in all areas of academics and life. People communicate with others everyday and written communication is especially challenging.

Written communication in mathematics tied into the school improvement plan of reading and writing. The students need to increase their reading comprehension and be able to write

confidently. In solving problems, my students had to read and comprehend the problem before attempting to solve. They also had to write about their solutions, which was my primary goal. Reading and writing is encouraged across the curriculum, so my problem of practice fit nicely into the school improvement goals.

Finally, I believe that writing about problem solving helped my students improve their problem solving skills. They examined what they knew and made conjectures, and then they evaluated these conjectures and reasoned through the processes. They reviewed their work for correctness and their answer for reasonableness. All of this process helped my students become confident problem solvers. If I helped improve the communication and problem solving skills of my students, then I believe this problem of practice was very important.

### **Literature Review**

Communication and problem solving are two important issues in reform mathematics today. The National Council of Teachers of Mathematics (NCTM) identified these processes, along with reasoning and proof, and connections and representations, to play a major role in their resource, *Principles and Standards for School Mathematics* (2000). This document has had an enormous impact on mathematical reform, state and local standards development, curriculum decisions, assessment guidance, and instructional research in the United States. These five processes were identified for all levels, kindergarten through twelfth grade.

Writing in mathematics can help students organize their understanding of mathematical concepts (NCTM, 2000). Upon examining research in the field of writing in mathematics, several themes arise. There is research that studies how a student's writing can help a teacher to understand the processes that a student is experiencing when solving problems. There is also research that examines whether the writing process will help a student develop problem solving

skills. Many researchers have also used writing to examine how confident a student is feeling about their problem solving abilities. Other themes included the investigation of the wording of problems, the breakdown of the processes of problem solving, the teacher's views on written communication and specific instructional practices to develop written communication skills.

Research shows that writing about mathematics can be used as a learning tool to improve problem solving and as an instructional tool to help the teacher make decisions. Goldberg (1983) noted that "If it's a question of writing, never underestimate the power of students to simultaneously delight and depress their teachers" (p. 421). Students provide valuable information when writing their explanations to a problem. For example, it can be what they know, or what they do not know. Writing can also be used to investigate student attitudes about mathematics.

The literature guided my action research decisions. I was interested in investigating how writing about problem solving can be used as a learning tool by the student and as an instructional tool by the teacher. I included student attitude and perceptions of strengths and weaknesses in my action research project.

### **Writing as a Learning Tool.**

There are many ways that writing can be used to promote learning. Cummins (1991) studied 24 first graders who were drawing pictorial representations of word problems. She investigated how students make sense of these problems and why they make certain errors. She also was interested in how the representations helped the students to arrive at their answers. She found that her students improved in their problem solving skills, probably because they were having experiences in problem solving.

Rudnitsky, Etheredge, Freeman and Gilbert (1995) studied 401 third and fourth grade students from 21 classrooms in six schools. They examined two treatment conditions, a writing treatment and a solving treatment. The writing group looked at the structure of problems and wrote questions from given information. The solving group received instructions in how to solve different types of problems. The researchers found that students receiving both treatments performed better at problem solving than the control group. The writing treatment group outperformed the solving group and the long-term retention was better for the writing group over both the solving group and the control group. They concluded that the students were learning the structure of word problems, which enabled them to outperform the other groups.

Pugalee (2001) dealt primarily with writing as a learning tool. What can student writing reveal about student learning? What is the process? He investigated 24 Algebra students and their mathematical writing about problem solving. He classified all student responses into four phases of problem solving; orientation, organization, execution and verification. He was then able to analyze each phase of problem solving. He concluded that the most time is spent in execution of the problem and that writing about the solution can identify where the student is struggling.

Pugalee's 2002 research involved 40 eighth grade algebra students. These students received training in describing their mathematical thinking. Two classes, of differing ability levels were selected and received the same instruction in written communication. It was noted that each of the classes showed improvements in writing, especially in the areas of generalizing and relating. This increase shows a deeper mathematical understanding of the concepts. Pugalee concluded that the student's writing abilities and mathematical reasoning improved following the teacher's focus on written communication.



Lim and Pugalee's (2006) action research examined the effects of writing in a tenth grade applied mathematics class. The students had many writing assignments, including writing about problem solving. The instructor commented on these solutions, which helped to clear up misunderstandings of mathematical concepts and helped the student develop strong communication skills.

All of these researchers found that writing promoted mathematical understanding. However, each approached the subject in a different way. Cummins (1991) looked at pictorial representations in young children, Pugalee (2001) was interested in the processes that students use to solve problems and their writing about problem solving assisted him in this evaluation. Rudnitsky, Etheredge, Freeman and Gilbert (1995) investigated how the structure of the problem and problem solving strategies could have an influence on the students' performance. Finally, Lim and Pugalee's (2006) action research was writing intensive, they were interested in how writing can affect students and their understanding.

My research dealt with writing about problem solving. I, too, was interested in how writing would affect mathematical understanding. I studied a class of ninth grade algebra students. The students experienced different problem solving strategies and then wrote their own solutions to other problems. What did my student writing tell me about their understanding? How can writing affect that understanding?

### **Writing as an Instructional Tool.**

Writing has long been used as an instructional tool. Teachers use student writing to assess student understanding, to analyze instructional strategies and to make curricular decisions. Cummins (1991) used her research to find errors caused by reading misinterpretations and found that experience improved her students' performance. The representations helped her to

understand the learning process of these students and helped her make instructional decisions. Her second experiment dealt with rewording the questions to eliminate ambiguity. These students' representations were more accurate than their previous attempts.

Chapman (1997) investigated three teachers and their strategies of problem solving and their ways to make sense of their student solutions. This included reflective communications from their students about the metacognitive behaviors associated with problem solving. These reflections allowed the teachers to understand the processes that their students were following.

Rudnitsky, Etheredge, Freeman and Gilbert (1995) analyzed how best to tackle problem solving. Their writing treatment involving the structure of language was more effective than problem solving strategies; however, both resulted in an increase in performance. They also concluded that experience was likely to improve performance. Pugalee (2002) also was investigating effective problem solving strategies, with an emphasis on writing.

Pugalee's 2001 research was also an instructional tool, but not for instructional strategies. Instead, he was investigating student learning and the metacognitive happenings, as the student solves problems. Metacognitive events involve people reasoning about their own thinking, or considering their own mental activities.

Lim and Pugalee's action research (2006) was an in-depth study of writing. The tenth grade applied mathematics students had many opportunities to write; such as journals, autobiographies, free-writing, formal reports, portfolios and tests. All of these experiences provided the researchers with instructional tools regarding information about student understanding, student attitudes, instructional strategy success/failure, and student performance. This information was invaluable for decisions that needed to be made involving reteaching, assessment, lesson planning, strategy use, and even curricular decisions.

All of these researchers used writing as an instructional tool. The writing activities focused teacher decisions, but in very different ways. Cummins (1991) found an increase in student performance based on rewording problems. Chapman's study (1997) was centered on the teachers and the way that they taught problem solving. The writing activities directed their strategies. This was similar to Rudnitsky, Etheredge, Freeman and Gilbert (1995), who examined different writing strategies to help increase problem solving performance.

Pugalee's studies (2001, 2002) were based on understanding how language impacts understanding. The student's written communication can provide evidence of understanding, and maybe more importantly what exactly the student does not understand. This written communication has the ability to focus teacher changes, in instruction, re-teaching and evaluation. One of the goals of Lim and Pugalee's action research (2006) was to improve teaching practices. The wealth of information from writing provided an opportunity for teacher reflection of instructional practices, assessment, and individual student needs.

My action research involved writing, used as an instructional tool. It allowed me to assess my students understanding of problem solving and expertise in written communication. It gave me an opportunity to address individual student strengths and weaknesses. This research allowed me to focus my re-teaching efforts in specific areas. The project enabled me to reflect on my instructional practices. This project helped me to make curricular decisions regarding written communication in my classes.

### **Writing to Investigate Student Attitudes.**

There are many types of mathematical writings. There are formal written explanations of problem solving which describe the processes that the student progresses through as the solution is reached and justified. Then there are the more informal types of writing: student journals,

surveys and questionnaires. These writings allow the teacher to understand how the student is feeling about their mathematical prowess. Miller (1991) in her review of using writing to learn, commented that some students who are unwilling to ask questions in class will instead write about their struggles. She also comments that students need to feel that the teacher values their thoughts, feelings, and ideas.

Lim and Pugalee's (2006) action research included student attitude writing: such as journals, free writing, anonymous questionnaires, and math autobiographies. They found that students expressed their frustrations and confidences, likes and dislikes. The students enjoyed the journals but disliked the free-writing. They did not see the purpose and the researchers decided to use more structured prompts. They wanted the students to reflect on the work for the week. What had they learned? What were their goals? Journal writing can provide many of these answers.

Student attitude was included in only a couple of the research articles. However, each author felt that these writing provided valuable information to the teacher. How was the student feeling? What was the level of frustration? Most teachers think that they can read their students; however, as Miller (1991) noted teachers cannot interact with every student every day. However, in a writing activity each student can communicate with the teacher. I included student feelings in my action research project. I wanted to know pre-treatment and post-treatment what the students are thinking and feeling. This information will lead to important changes in my instructional strategies and individual student assistance.

### **Conclusion: Literature around Writing Mathematics**

My study examined writing about problem solving in a ninth grade algebra class. Lim and Pugalee (2006) investigated a tenth grade class and Pugalee (2002) looked at an eighth grade class. I believe that communication skills are very important and that problem solving plays a

vital role in mathematical learning. NCTM (2000) states that “writing in mathematics can also help students consolidate their thinking because it requires them to reflect on their work and clarify their thoughts about the ideas developed in the lesson” (p. 61). This time for reflection allows students to organize their thoughts, execute their plans and justify their answers.

Hembree (1992) evaluated 487 reports concerning problem solving. A format consisting of well-developed representations was found to have the largest increase in performance. The best performers were students who shifted easily between words and mathematics. However, mental development was also seen to be a factor.

My research was with middle school students. I believe that my training as a Math in the Middle participant allowed me to have a different focus from a typical middle school teacher. In every aspect of the MIM program, we have seen the importance of problem solving. Lester (1994) in his review of problem solving research, comments that problem solving is the most written about topic in mathematical curriculum, but the least understood. The study of metacognitive behaviors and the communication of those behaviors should be a primary area of research. This is what I wanted for my research.

### **Purpose Statement**

The purpose of my project was to improve written communication about the solving of mathematical word problems. I wanted to investigate my students’ confidence levels and determine the effects of this action research on my teaching style. I examined the variables of student written expression, effective problem solving strategies and student confidence in problem solving in seeking to answer these research questions:

- ❖ What will my students’ written explanations to word problems look like after I model how to write solutions?

- ❖ What problem solving strategies will my students use to solve problems?
- ❖ What will happen to students' confidence in solving word problems after I model how to write solutions?
- ❖ What does my teaching look like when I try to better teach problem solving to my students?

### **Method**

My ninth grade algebra class was the focus of my research. Data collection started the last week of January 2008, with a pre-attitude survey (Appendix A). These surveys asked questions about students' feelings on many topics. These topics included problem solving, mathematics skills, and writing about mathematics. Student interviews were conducted this week concerning what strategies they use when solving problems, what they feel most and least confident about when solving problems and their ability to explain their solutions to others (see Appendix B for interview questions). I recorded these sessions on a tape recorder and transcribed the surveys on paper for my files.

Problem solving activities began the first week of February. The students worked in groups and solved a problem involving working backwards from given information. After they handed in their solutions, we discussed what a good solution looked like. We continued problem solving throughout February, March and April. In all cases, the students worked in groups of two or three. They handed in individual solutions to each problem, which were evaluated using a rubric (Appendix D). The activities involved working backwards, drawing a picture, making a chart and finding a pattern. In April, students were given a variety of problems that involved using the strategy of their choice.

Another form of data was journals. After each strategy, the students answered questions in their journals about that strategy. In this journal, the students answered questions regarding the

strategy that the class had been using. These solutions and journals were kept in individual folders in the classroom. I also journaled every week about the problem solving activities. I recorded information including changes I had seen in my students, both in their writing and in their confidence. I also noted what my teaching looked like for that week.

At the end of my research project, the first week of May, post-surveys were given (Appendix A). The students were interviewed a second time about their problem solving activities and they were asked to solve a problem involving finding patterns (see Appendix C for post-interview questions). I again recorded these sessions on a tape recorder and transcribed them later.

In, May, I analyzed the data, student written solutions, journals, interviews and surveys. I charted data on the surveys and found the mean and standard deviation for each question. I also examined my teacher journal. I looked for evidence concerning each of my research questions.

### **Findings**

My action research involved the improvement of my students' written communication of problem solving activities. My target class was ten students in ninth grade Algebra I there were five girls and five boys. The class was divided into groups of two or three depending on the attendance for the day. The students rearranged the room so that each group could have its own space. A copy of the problem was given to each student. One student read the problem aloud and clarifications were given if questions were asked.

The problem solving looked different at the beginning of the research compared to the last couple of weeks. In February, the students would sit and look at the question and wait for me to help them. They would work for awhile and then wait for me to help them. I would ask questions and the students would write down what they had said. This was a long and laborious experience. The solutions were short and contained mostly mathematical calculations. My students were relying on me to provide guidance and obviously wanted me to tell them the process.

Slowly, the problem solving changed. I decided to stop answering questions instead I asked questions. These questions included “Tell me what you know”, “What do you think?” and “What have you done so far?” These questions frustrated some of my students, but they quickly realized that I was not going to give them either the answer or the process. The discussion between group members was interesting to watch. They began debating about how to solve the problem. I especially enjoyed the days when the students realized that a certain problem could be solved using multiple strategies.

The students slowly learned to rely on each other. There reached a point in the semester when I realized that my students had stopped relying on me! I watched amazed at their progress. They were working cooperatively and brainstorming together about which method they wanted to use. There was even discussion about how they were explaining their answers. The students asked me very few questions and these were not questions concerning problem solving, they were mainly math computation questions.

At the end of the research, the students were eager to break into groups and dive into the problem solving process. They were comfortable with most groupings and looked forward to problem solving activities. There was discussion about the problem solving strategy that they were going to use. Some groups even solved the problem in more than one way, and then chose which way they thought was best. I was also impressed at the effort they put into helping each member of their group. They wanted their entire group to understand not only the answer, but also the process.

My classroom atmosphere had changed dramatically. My involvement in this process was very limited. I listened when they were excited about their discoveries. I monitored group cooperation and involvement. I was no longer in control of the student learning, they were in control. They enjoyed this new role and seemed anxious to engage in discussion regarding the next problem solving activity. I marveled at how quickly this classroom transformation had taken place. Every day did not go smoothly, but there was a definite change.



My first research question was “What will my students’ written explanations to word problems look like after I model how to write solutions?” I found that my students’ written communication improved over the course of this project. The writings included more diagrams, charts and tables. The students wrote complete sentences and used mathematical terms. The solutions contained information about what information they started with, why they used the chosen operations. Some solutions also included a justification of the answer.

The student work supports this assertion. At first, the students would only write numbers and the operations that they were using. They did not even write whole sentences. For example, on the first problem solving activity, one student wrote, “First you take 15 times 30 which equals 450.” That was the extent of the explanation. One of the latest assignments from the same student includes the explanation, “The 15 foot rope would have a larger circle. He will walk 31.42 feet farther.” A second example is a student who wrote, “We took 30 times 15 and got 450 sentences.” In a later assignment, this student stated, “Paula’s horse travels a greater distance with the 15 foot rope. He travels 62.8 feet with the 10-foot rope. He travels 94.2 feet with the 15 foot rope, the distance farther is 31.4 feet.” This explanation is followed by the calculations. There was definitely improvement. A third example is a student who had some math calculations on her sheet and then simply stated, “We worked backwards, started with the 2.” In a later assignment, she was determining which pizza to choose. She found the area of each slice and stated, “The one/eighth slice of 12 inch pizza is the biggest because it has a greater area.”

In my teacher journal, I noted students writing more on their solutions; instead of just writing numbers, they were starting to explain their thinking. I asked for a definitive answer, instead of just circling the answer. One of my students did not like to write anything down. After my question, “where is your answer?” the student wrote “It took the snail 10 days to get out of

the hole.” I was pleased to get an entire sentence! I observed that my students are prompting each other in their written explanations. One student asked another student, “Did you explain your pattern?” They also asked each other for suggestions. A student commented, “I can see the pattern, how did you put it in words?”

Another item to support the improvement in writing is the student interviews. When I asked my students if they thought their writing had improved, every student answered yes. One student commented, “I use the right words.” Another student said, “My explanations are longer and better.” A third student stated, “I now know how to write down information so other people understand it.” When asked to choose a favorite activity, one student replied, “It was my favorite because my explanation was good.”

I believe that my students’ writing improved because they practiced this skill. The problem solving writings were evaluated using a rubric. The students could look at their evaluation and determine where they needed to improve their grade. The students wrote complete sentences that included information about where they started, operations they chose and justification of their answers. The writings also included diagrams, tables and pictures. I believe the explanations improved because the students worked together in groups. This cooperative grouping led to brainstorming new ways to explain their problem solving.

My second research question is, “What problem solving strategies will my students use to solve problems?” We examined a few different strategies during this project; the strategies of working backwards, drawing a picture, finding a pattern and making tables. However, the students have not limited themselves to these strategies. They also made diagrams and flow charts to organize their thoughts and they sequenced their steps to a solution. In the post-attitude survey, nine of the ten students agreed with the statement, “I know and can use a variety of problem solving strategies.”

I have observed students suggesting different ways to their group to solve the same problem. Some students chose to show two different ways to solve a problem. One student noted in her journal, “I started with the long way, and I came up with the same answer as someone else in my group who did it the short way.” Another student commented, “There is more than one way to solve this problem.” I accept and show alternative methods in my classroom. However, it was still a revelation to some of my students that there could be more than one way to solve a problem. In addition, my students have found a variety of approaches to check their solutions.

My students used interesting ways to organize their data. These ways included pictures, tables, tree diagrams and flow charts (see Appendix E for student work). I seemed I stifled the students’ creativity when I provided a chart for them. They much preferred creating their own organizational diagrams. Seven of my ten students said that their favorite type of problem solving strategy was drawing a picture. One student said, “It is easy to look back on and understand.” Another student stated, “It makes the problem more real to me.” Five of the seven who preferred drawing said that it made the problem easier.

My students used many different strategies to solve problems (see Appendix E for sample student work). I believe this was a result of examining different strategies to provide my students with an arsenal of methods to attack problem solving. After some experience with these strategies, the students were able to choose which strategy they felt fit the situation. They also chose strategies, such as sequencing, that we did not discuss as a class. I believe that my students’ use of different strategies was encouraged by cooperative grouping. The students shared ideas on interpreting, solving and explaining their problem solving activity.

Examining student confidence in problem solving and the writing of written solutions was my third research question. My pre-attitude surveys clearly showed that my students lack

confidence when solving word problems. Only one student marked that he or she strongly agreed that problem solving was easy. Eight of the nine students surveyed expressed frustration or confusion when solving word problems. Here are some of their responses: “It can get confusing when you first look at it” “Sometimes it gets frustrating because of how they word it” and “I do not understand them.” The interviews also revealed that there was a confidence problem. When my students were asked what they felt least confident about when solving word problems, most responded that they struggle with reading the problem and deciding what to do. Some commented that when there are many numbers in a problem, they get confused. One student commented that they could solve equations, but could not write the equation. Two commented that they had no idea where to start on a word problem.

In my teacher’s journal, I wrote about the reason I chose this project. I saw my students struggling with word problems. They want me to solve their problems, or help them set up the equations and then they can solve the equations. They do not understand that the purpose of the word problem is to see if they can reason out how to solve it. They experience great stress and frustration when presented with problem solving.

During the project, I saw evidence of an improvement in confidence. My students worked in pairs or small groups to solve word problems. I was impressed with the cooperation and discussion that I observed. I wrote about their struggle and collaboration. I did not see students giving up; instead, I saw support and teamwork. I was pleased with their effort. The student journals showed evidence of this improvement. For example, a student stated, “It is easier to understand when we draw a picture.” When finding patterns, one student journaled, “I felt successful with this strategy.”

As my research progressed, I found that the students were confident and started to work on the problem quickly. At the beginning, they would wait for me to come and help them start and then wait for me to return to check their work. Near the end of the project, they started discussing ideas with their partners immediately. It did not matter who the partner was, they dove right in and started brainstorming. For example, I have a student who is very hesitant about his problem solving skills. He became actively involved in his group. At the beginning of the action research project, he would not offer any ideas. Later, he questioned others in his group about their ideas and computations. He has more confidence than I could have hoped!

The post-attitude surveys and interviews also showed evidence of an increase in confidence levels. Six of the ten students agreed with the statement: "Problem solving is easy for me." Eight of the ten agreed with the statement, "I am good at math." When asked on the survey to describe how they felt about solving word problems, nine of the ten students responded that they enjoyed the activities that we had. Six students said that although it can be confusing, they struggle through it with their group and find a solution. An interview question was, "How do you feel about our problem solving activities?" All ten students replied that it was fun. Some remarked that they enjoyed working problems as a group and had less homework.

My students developed confidence in their problem solving skills. I believe there are many reasons why the students changed confidence levels. Prior to this action research, the students had limited experience in problem solving. By providing an opportunity to solve problems, they developed skills and strategies to use. The group effort in solving problems allowed the students to share ideas, and strategies. There was extensive discussion in the small groups about the problem. This cooperative setting was ideal for confidence development. The small group allowed for less risk taking for students who were unsure of their answers. Other

students were available to help. All of these factors, combined to provide an opportunity for students to become confident in problem solving.

My last research question dealt with my teaching, “What does my teaching look like when I try to better teach problem solving to my students?” My teaching style changed dramatically, and the students took more responsibility for their own learning. I allowed them to experience problem solving in small group situations instead of a class lecture situation. My students helped each other and became more confident in their problem solving abilities.

My first teacher journals reflect the transition that was happening in the classroom. The students would look to me for help in their problem solving activities. They would wait for me to go around the room and help each group. I struggled with not giving them the answers. The week of February 4, I wrote, “Nothing went well this week! The students struggled to understand the problem and they wanted me to tell them the answers. They are not trying to improve their written solutions.” The last week of February, I wrote, “The students are more receptive to the problem solving activities. They are also open to different groupings of students. They start to work right away and have excellent discussions.” For the week of March 10 the entry read, “There was great group cooperation and discussion. I only answered one question and this was to clarify the question. They are not even looking for me, and obviously do not need my help.” The students worked independently and supported each other.

Another change in my teaching is how I assisted my students. I noted in my journal, that I was trying to ask questions, instead of answer them. When a student asked me how to solve a particular activity, I asked them, “What do you know?” Sometimes this led the student to suggest possible ways to solve the problem. Another time, all I had to ask was “explain what you have done so far.” As they were explaining they realized where their mistake was, and they were

happy that they had answered their own question. This change in my teaching did not come easily to either my students or me.

My teaching has changed and my students have changed. It was difficult for my students at the beginning of this action research. In the past, they had looked to me for guidance and answers. I was used to rescuing them when I saw that they were struggling. My students transitioned more quickly and more easily than I did. After they realized that I was there to ask questions instead of answer, the students quickly looked to each other for discussion and assistance. I sat at my desk to write a few notes in my teacher journal and often noticed that students were not even aware that I was in the room. They were in control of the problem solving activity and doing quite fine without me!

### **Conclusions**

This action research has impacted my students and me! Some of the changes are dramatic and some are subtle. My students' written solutions to mathematical word problems have improved. Their confidence levels in writing and in solving math problems have increased. The students know that they have many strategies from which to choose. Because they were solving problems in a group setting, they were able to support each other and be responsible for their own learning.

These findings agree with Pugalee (2002), who reported an improvement in writing and mathematical reasoning following an emphasis on writing math solutions. Rudnitsky, Etheredge, Freeman and Gilbert (1995) also noted that experience improved the performance in writing about problem solving for their students. The action research project by Lim and Pugalee(2006) studied writing in a math class. They used their students' writings to make instructional decisions

and study their students' attitudes about the mathematics they were learning. This was also a purpose in my action research project.

I have used mathematical writing as a learning tool and an instructional tool. The writings have helped my students learn new concepts. Cummin's research (1991) showed that writing enhanced mathematical understanding. My students' writings have shown me what they know and how they are thinking. Miller (1991) noted the value of student writing, as a way to understand the students, and as a means for the students to communicate individually with the teacher.

My last conclusion is that my teaching has changed. I am no longer the holder and imparter of all wisdom. I observed the changes in my students. I wondered at my purpose and role. My students needed opportunities to solve problems, to make mistakes and to help each other. I stood back and listened. I asked questions instead of answering them. I let my students control their learning. My action research that was designed to change my students ended up changing my teaching.

### **Implications**

I plan to use this project to guide my teaching next year. I want to include problem-solving activities in all of my classes. It is very important that my students develop skills, not only in problem solving, but also in written communication. These activities will help my students improve their confidence in both areas. I also want to continue to use group work as I believe that the students are able to support each other.

The implications to my teaching are more difficult to determine. This has been a new experience for me. I need to find and develop new opportunities for my students to problem solve. This changes my teaching role to that of a facilitator. I need to become adept at identifying



students who are struggling and provide them with guidance but not answers. I also need to find new ways to help my students develop their written communication skills. My action research has reinforced my belief that problem solving and communication skills are essential in the mathematical learning process.

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## Appendix A

**Student Survey:****Date** \_\_\_\_\_

Please place an X in the column that you feel is most accurate. Use the code below for each category.

**SD-Strongly Disagree, D-Disagree, U-Unsure, A-Agree, SA-Strongly Agree**

	<b>SD</b>	<b>D</b>	<b>U</b>	<b>A</b>	<b>SA</b>
<b>1. I enjoy solving problems.</b>					
<b>2. Problem solving is easy for me.</b>					
<b>3. Mathematics is not important in every day life.</b>					
<b>4. When I get stuck on a problem, I stop working.</b>					
<b>5. I know and can use a variety of problem solving strategies.</b>					
<b>6. I like to write.</b>					
<b>7. Writing about mathematics helps me understand the problem.</b>					
<b>8. Others can understand how I solve problems by reading my written explanations.</b>					
<b>9. It is important to write about math problems.</b>					
<b>10. I am good at math.</b>					

**11. Describe how you feel about solving word problems.**

## Appendix B

### Interview Questions:

#### At the beginning of the research:

1. How do you feel about solving word problems? Why do you think that is?
2. What do you feel most confident with in solving word problems? Why do you think that is?
3. What do you feel least confident with in solving word problems? Why do you think that is?
4. What strategies do you try when solving math problems?
5. Can you explain how you solved a problem to others? Explain your process.
6. What would you tell someone that it takes to be successful in this math class? Please be very specific.

## Appendix C

### Interview Questions:

#### At the end of the research:

1. How do you feel about solving word problems?
2. What do you feel most confident with in solving word problems?
3. What do you feel least confident with in solving word problems?
4. What strategies do you try when solving math problems?
5. What is your favorite type of problem solving strategy? Why?
6. Do you like to work math problems in a group? Why or why not?
7. Do you like to write about problem solving? Why or why not?
8. Which of your written explanations were you the proudest of? Why?
9. How has your writing improved?
10. How do you feel about our problem solving activities?
11. Please solve the following problem and explain to me your thought process as you work the problem.  
  
**A rancher raises ducks and cows. If he goes out one morning and sees 5 heads and 12 legs in the barn, how many of each animal does he have in the barn?**
12. What would you tell someone that it takes to be successful in this math class? Please be specific.
13. What advice would you give me about problem solving as I make plans for next year's math class?

## Appendix D

**Rubric for assessing written explanation of word problems.**

<b>Characteristic</b>	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>
<b>Strategy</b>	<b>Reasonable Strategy chosen and used correctly.</b>	<b>Reasonable Strategy chosen but not used correctly.</b>	<b>Strategy chosen was incorrect, but there was some development.</b>	<b>Strategy chosen was incorrect and no development was given.</b>
<b>Calculation</b>	<b>Correct calculations were chosen and used accurately.</b>	<b>Correct calculations were chosen, but some were inaccurate.</b>	<b>Calculations were not completely shown, many errors.</b>	<b>Very little evidence of any calculations.</b>
<b>Written Explanation</b>	<b>Solution is presented in an orderly manner, correct terminology used.</b>	<b>Solution is presented in an orderly manner, there are minor errors in explanation.</b>	<b>Solution is not presented in an orderly manner, incorrect terminology is used.</b>	<b>Very little explanation is given, no organization.</b>

Appendix E – Sample Student Work



Perplexing Pizzas

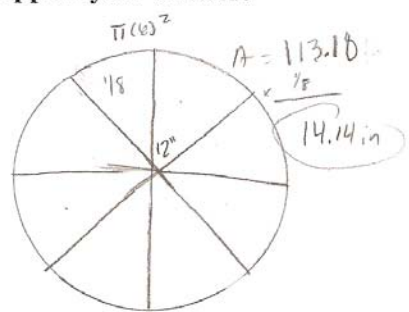
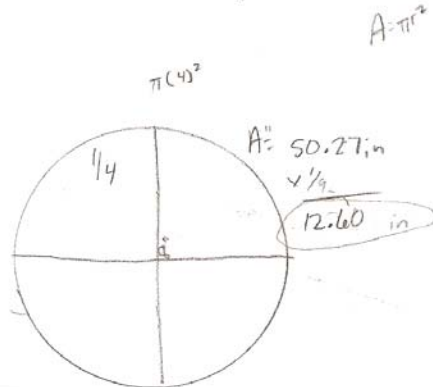
Tamara was very hungry. Her tricky brother offered her 3 choices of her favorite pizza.

Choice 1: 1/4 of an 8 inch pizza

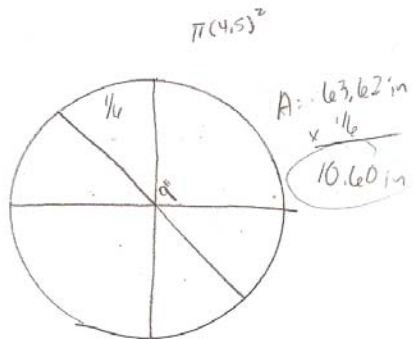
Choice 2: 1/6 of a 9 inch pizza

Choice 3: 1/8 of a 12 inch pizza

Which choice would be more pizza? Draw diagrams to support your answer.

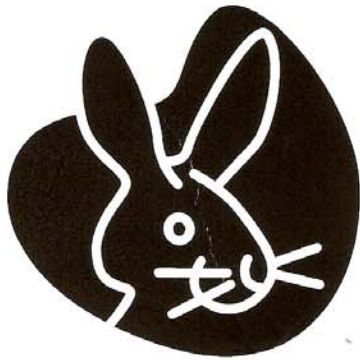


1/8 slice is the biggest because it has a greater area.

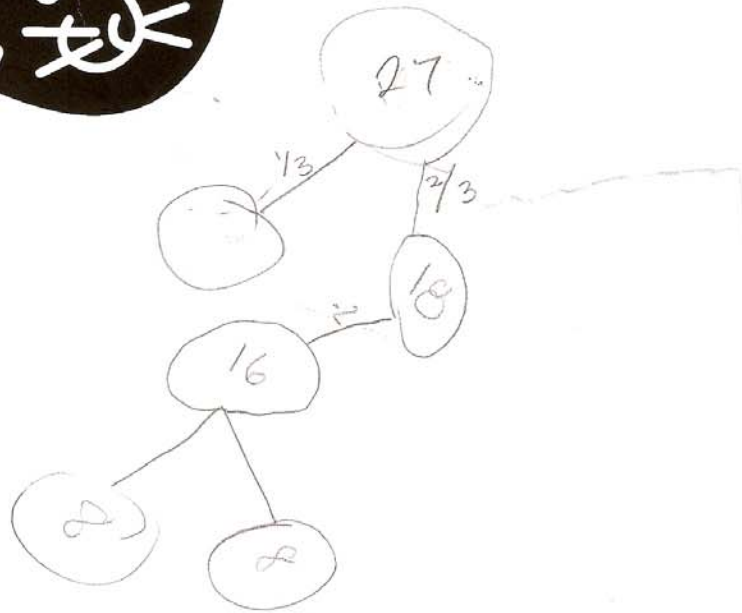


## Bunny Trouble

Kaegan raised bunnies. He decided to decrease his bunny population. He gave  $\frac{1}{3}$  of his bunnies to his cousin, Sally. Two bunnies broke out of their cages and ran away. Of the remaining group, he sold half at the exotic animal sale. At the very end, he had 8 bunnies. How many did he start with? How many did Sally receive?



$$8 + 8 = 16 + 2 = 18 \times \frac{1}{3} = 6$$



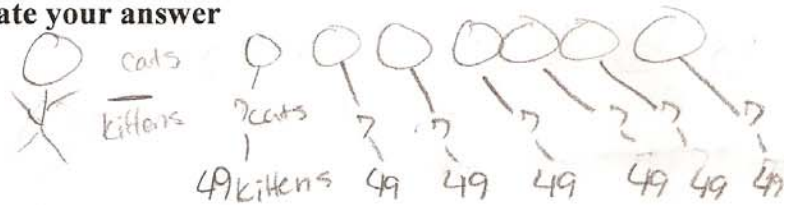
27 rabbit at beginning, gave  $\frac{1}{3}$  to sally which is 9 bunnies.  
 2 escaped then sold 8 at the sale and ended with 8 bunnies



### Cats, Cats and more Cats

Seven girls boarded a bus. Each girl had seven backpacks, each backpack had seven cats. Each cat had seven kittens. How many legs were on the bus?

Draw a picture to illustrate your answer



56 cats + kittens in each backpack

$$7 \times 7 = 49 \text{ backpacks}$$

$$\begin{array}{r}
 49 \times 56 = \\
 \times \quad 2,744 \text{ cat legs} \\
 \hline
 \quad 14 \text{ legs per cat} \\
 \hline
 \quad 10,976 \text{ cat legs} \\
 + \quad 14 \text{ girl legs} \\
 \hline
 \end{array}$$

10,990 total legs on bus!

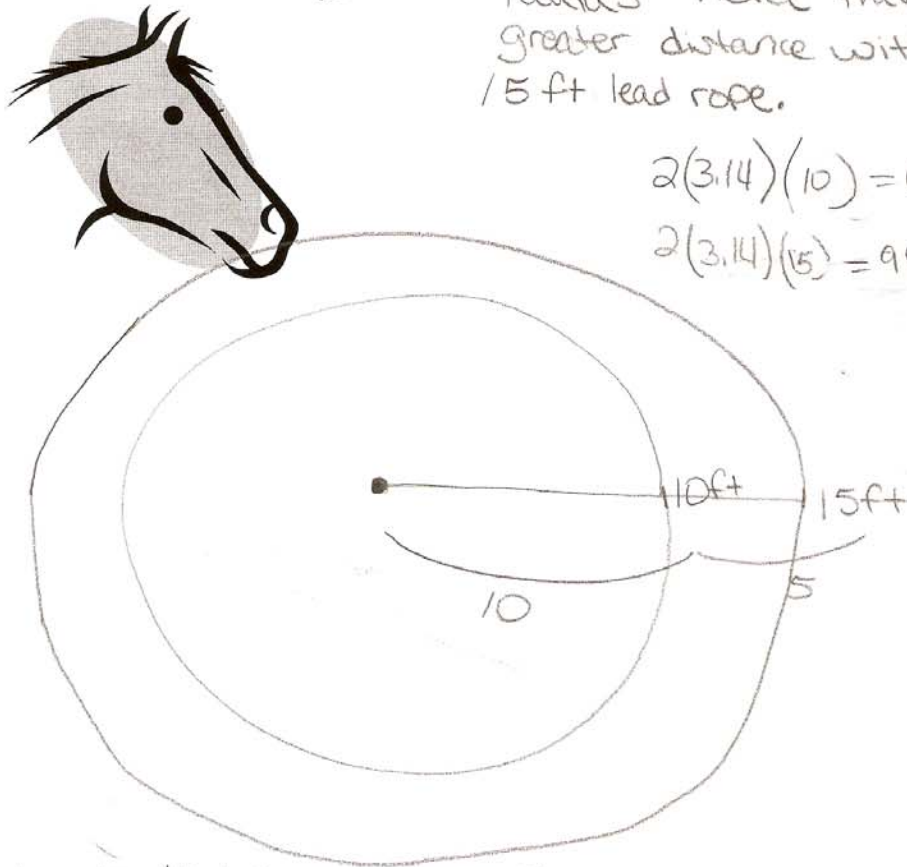
## Come On Nelly!!

Paula is exercising her horse. She has two lead straps, one that is ten foot long and one that is 15 foot long. With which rope does her horse travel a greater distance, how much farther? Draw a picture to support your answer.

$2\pi r$  Paula's horse travels a greater distance with the 15 ft lead rope.

$$2(3.14)(10) = 62.8$$

$$2(3.14)(15) = 94.2$$



He travels 62.8 ft with the 10 ft rope  
 He travels 94.2 ft with the 15 ft rope  
 the distance farther is 31.4 ft.