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ABSTRACT

The purpose of this project was to examine the levels of achievement and metacognition in expressing mathematics understanding and problem solving processes by students in a second grade classroom when the students used writing in daily mathematics learning according to their scores on a mathematical problem solving assessment and individual interviews. This paper concludes that through daily writing activities that involve expressing mathematics thinking, problem solving, and the creation of word problems, students' mathematics achievement and metacognition increased. (Contains 31 references.) (ASK)

# The Effects of Writing in Mathematics on Second-Grade Students' Achievement and Metacognition

by

Rachel A. Card

This project has been completed in partial fulfillment of the Master of Arts in Teaching Degree in Elementary Classroom Teaching; Saginaw Valley State University, College of Education, Winter, 1998.

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**Dedication**

I dedicate this research project to my second-grade class of 1997-1998, and my daughter, Emily, for their inspiration in demonstrating and sharing the joys of exploration, curiosity, and laughter.

**Acknowledgements**

I would like to acknowledge my husband and my mother for their tremendous support, understanding, motivation, and love throughout my graduate experiences at Saginaw Valley State University which allowed me to reach my greatest potential in completing my Master of Arts Degree.

"Everything in life has a purpose. There are no mistakes, no coincidences. All events are blessings given to us to learn from."

-Elizabeth Kubler-Ross

## TABLE OF CONTENTS

The goal of mathematics education has been promoting the learning of mathematical thinking. In order to think mathematically, one must develop and be able to use the processes of mathematics in order to make sense in dealing with mathematical abstraction (Schoenfeld, 1992). The National Council of Teachers of Mathematics (NCTM, 1989) emphasizes communication as a necessary focus for grades K-12. The use of language and symbolism to communicate mathematical ideas has become a priority in any mathematics curriculum. Students of mathematics must be able to reflect upon and clarify their thinking and express ideas both orally and in writing (NCTM, 1989; Brown, 1997; Kroll & Halaby, 1997; Helton, 1995; Wason-Ellam, 1987; Linn, 1987). The means of connecting mathematical thinking with mathematical communication is through the solving of problems. Consequently, problem-solving is a necessary skill that students must be taught in order to develop into productive citizens (NCTM, 1989; Matz & Leier, 1992; Silverman, Winograd, & Strohauer, 1992; Rudnitsky, Etheredge, Freeman, & Gilbert, 1995; Wilborn, 1994; Kjos & Long, 1994; Butkowski, 1994; Silver, Shapiro, & Deutsch, 1993).

An effective way to develop mathematical thinking, communication, and problem-solving is through the use of writing in the learning of mathematics (Burns, 1995; NCTM, 1989; Kasparek, 1996). There is direct link between writing and learning. Using writing to learn in a content area requires students to analyze, compare, and synthesize information (Hillary, 1996).

This results in the establishment of concepts through making connections between old and new knowledge (Vygotsky, 1962; Caine & Caine, 1994; Mastin, 1996; Wason-Ellam, 1987).

Many teachers of mathematics believe that writing should be a daily component of mathematics instruction. If students can communicate their understandings of mathematical concepts effectively through writing, they most likely understand those ideas (Burns, 1995; Brown, 1997). Writing has been an effective means by which problem-solving strategies have been taught (Rudnitsky, Etheredge, Freeman, & Gilbert, 1995; Wilborn, 1994; Kjos & Long, 1994; Butkowski, 1994; Silver, Shapiro, & Deutsch, 1993; Matz & Leier, 1992; Silverman, Winograd, & Strohauer, 1992). Having students write about a process or problem requires them to clarify their thinking. The task of writing, therefore, becomes an integral component of the thinking process. Students are forced by writing to become active rather than passive learners, and they are more likely to be actively involved in constructing their own knowledge (Burns, 1995; Wason-Ellam, 1987; Kroll & Halaby, 1997; Caine & Caine, 1994).

One of the most effective ways to use writing to teach mathematics is through the use of journals (Vacca & Vacca, 1986). Journal writing extends and enhances students' abilities to express ideas, think critically, and communicate (Helton, 1995; Brown, 1997; Norwood & Carter, 1994; Kasparek, 1996; Linn, 1987; Wason-Ellam, 1987). Children learn mathematics through experiences that engage them in real-world situations (Perlmutter, Bloom, & Burrell, 1993; Caine & Caine, 1994). One way to help children identify situations where they must apply mathematics is through mathematics

journals. Journal writing both enriches mathematics learning and makes it meaningful and important to children (Vacca & Vacca, 1986; Helton, 1995; Brown, 1997; Norwood & Carter, 1994).

Another way to develop mathematical thinking and problem-solving is through the solving and writing of word problems and stories (Matz & Leier, 1992; Silverman, Winograd, & Strohauer, 1992; Brown, 1993; Kliman & Richards, 1992). Problem-solving strategies are best taught beginning in the primary grades through a variety of experiences and applications (NCTM, 1989; Brown, 1987; Matz & Leier, 1992). By writing down the thoughts and steps involved in each step of a problem solution, the student creates a clear picture for himself or herself through written words. The act of writing provides review, reflection, modification, and evaluation of the problem-solving process (Kroll & Halaby, 1997; Brown, 1997). Moreover, word problems and stories written by students are more challenging, creative, and interesting than traditional textbook story problems (Silverman, Winograd, & Strohauer, 1992). Mathematics stories written by students are more reflective of everyday problems which require broader uses of mathematics through performing calculations to obtain information, resolving dilemmas, making decisions, and determining what can be the next step compared to textbook story problems where typically one correct strategy and a numeric solution are required (Kliman & Richards, 1992).

An effective mathematics program employs writing as a tool to improve student conceptual understanding, metacognition, communication, and problem-solving skills related to mathematics (Burns, 1995; Kroll & Halaby, 1997; NCTM, 1989; Kasparek, 1996; Helton, 1995; Rudnitsky, Etheredge,

Freeman, & Gilbert, 1995; Linn, 1987; Wason-Ellam, 1987).

**Significance of the Project**

In past studies, the use of writing in mathematics classes has been examined through the use of math journals in a first-grade "hands-on" mathematics program, through the use of journal writing with high school geometry students, and through the implementation of a writing program integrated with a basic Algebra II textbook with high school students (Wason-Ellam, 1987; Linn, 1987; Kasparek, 1996). All three of these studies emphasize that when writing is used as an expression of students' mathematical thinking, students become more active in their learning, and learning becomes more personal and meaningful. Writing promotes a greater depth of thinking that forces the students to analyze and synthesize new information and become aware of their individual strengths, weaknesses, and learning processes. High-order thinking is developed as students move beyond merely memorizing and recalling information (Wason-Ellam, 1987; Linn, 1987).

In other studies, it is suggested that problem-solving strategies and higher-order thinking skills can be developed through using writing in mathematics. Silver, Shapiro, and Deutsch (1993) and Rudnitsky, Etheredge, Freeman, and Gilbert (1995) find that writing fosters thinking and reasoning skills, increases students' abilities to solve mathematical word problems, and promotes a greater retention of mathematical concepts and processes over a long period of time. In their studies, Wilborn (1994), Kjos and Long (1994), and Butkowski (1994), find that problem-solving, critical thinking, and higher-

order thinking skills in mathematics are improved through the use of writing in mathematics. Positive attitudes, confidence, and writing skills are also developed as well.

Mastin (1996) has conducted a study on how a concept-based mathematics program with journal writing promotes an effective use of mathematical language and use of inferences to draw conclusions in students compared to a skills-based program. Her research suggests that students in the concept-based mathematics program become more expressive and able to utilize problem-solving strategies. The students also connect prior knowledge with new knowledge more effectively.

Studies by Gibisch, Lumpkins, Sewell, and Vagena (1995) and Hillary (1996) support the use of writing across the curriculum. The researchers find that writing in all subject areas helps to strengthen critical thinking and writing skills. The research data also show that a curriculum integrated with writing promotes the positive attitudes of students toward writing.

Other benefits have also been indicated to evolve from using writing with mathematics. Hackett and Wilson (1995) find in their study that students who write in journals about mathematics concepts improve their abilities to use mathematical language in speaking and writing as well as improve their understanding of mathematics and attitudes toward mathematics. Miller (1992) suggests that teachers who read their students' mathematical writings gain a clearer understanding of the students' individual learning processes and understanding of mathematics. As a result, teachers also adjust and tailor their instructional practices to meet the learning needs of the students. Thus, the practice of using writing in the mathematics classroom becomes

much more dynamic as students develop skills in a variety of disciplines and teachers, who develop greater communication with students, become more competent in assessment and instruction and serve as better role models for students in becoming more proficient at expressing mathematical ideas (Hackett, 1995; Miller, 1992; Linn, 1994).

Many researchers agree that writing is a necessary part of daily mathematics instruction. Some experimenters cite the increased attitudes and achievement of students who use writing with mathematics (Wilborn, 1994; Kjos and Long, 1994; Butkowski, 1994). Other experimenters emphasize the development of thinking skills through writing with mathematics (Wason-Ellam, 1987; Linn, 1987; Silver, Shapiro, and Deutsch, 1993; Rudnitsky, Etheredge, Freeman, and Gilbert, 1995). NCTM (1989) places writing as a high priority by stating that the mathematics curriculum includes writing as a vehicle for both expressing mathematical ideas and providing opportunities for reflecting upon and clarifying mathematical thinking.

## Statement of the Purpose

The purpose of this project, therefore, was to examine the levels of achievement and metacognition in expressing mathematics understanding and problem-solving processes by students in a second-grade classroom in a medium-sized Michigan school district when the students used writing in daily mathematics learning according to their scores on a mathematical problem-solving assessment and individual interviews.

## REVIEW OF THE RELATED LITERATURE

The reviewed literature covered many different facets of writing and mathematical achievement. Some studies were included that supported the use of journal writing and writing prompts in the mathematics classroom. In addition, there were investigations that examined the effects of implementing writing programs in both mathematics programs and across the curriculum. Several studies examined the link between problem-solving and critical thinking skills and writing. Also, the development of communication skills, both written and oral, through mathematics and the benefits of student writing by teachers were found to be researched.

Information sought through the review of the literature included an understanding of the benefits of writing in the mathematics classroom, how writing enhances content learning and mathematical conceptualization, the connection between writing and higher-order thinking skills, metacognitive development through writing, and instructional practices that were effective in integrating mathematics and writing.

Wason-Ellam (1987) examined the usefulness of expressive journal writing in helping students to discover missing connections in their knowledge and explore relationships through reflecting on their learning. The study took place in a "hands-on" first-grade mathematics classroom. Over an eighteen-week period, students were asked to record their impressions of what they were learning. Questions were often used to prompt the students and focus their thinking prior to writing. The results showed that students used

writing for four different purposed: self-questioning, organizing information, assimilating and accommodating information, and making guesses. Students had begun the study by merely displaying knowledge. However, as they became more comfortable with writing to learn, they began to ask questions, arrange their experiences in chronological order, make connections between prior and new knowledge, reflect on both correct and incorrect answers, and make guesses. These findings suggested that using expressive and reflective writing made students actively engaged in meaningful and personal learning instead of learning restricted to memorizing, transcribing, and recalling.

Rudnitsky, Etheredge, Freeman, and Gilbert (1995) conducted a study that was aimed to design and test instruction that was intended to help students construct knowledge about addition and subtraction problems and determined if this knowledge would transfer to actually solving problems. The researchers tested two hypotheseses, (1) structure-plus-writing instruction would result in improved word-problem solving, and (2) this improvement would result in more enduring improvements in problem-solving than instruction based on practice and explicit rules and procedures. The participants in the study were 401 third-grade and fourth-grade students from twenty-one classrooms in six schools from rural and small-town communities. The populations were diverse both socioeconomically and culturally, with substantial Latin American and Asian communities. The problem solving of children taught through a structure-plus-writing approach was compared to a control group receiving no instruction in arithmetic word-problem solving and a group receiving instruction based mainly on practice and explicit heuristics. Data were measured through a

pretest, posttest, and retention test with each involving six word problems. Both hypotheses were supported by the results. The structure-plus-writing group achieved higher than the group receiving practice and heuristics instruction. Furthermore, the structure-plus-writing group both maintained outperformance and widened the gap as shown by a retention test administered ten weeks after the treatment. There was evidence that mathematics instruction based on problem structure and writing was effective in developing students problem-solving abilities.

In a study conducted by Linn (1987), the effects of journal writing on thinking skills were examined. A group of seventy-two high school sophomore geometry students from a small, rural Catholic school in Florida was used. Journals were used to express and record mathematical thinking for one year. Data were collected from the students' journal samples. The results showed that students became active in their learning. Writing forced the students to synthesize information and become aware of what they knew and did not know. The students became aware of their individual strengths and learning styles and began to utilize their strengths. The findings supported the use of student journals in instruction in all disciplines, particularly in mathematics.

Another study, conducted by Kasparek (1996), examined the effects of implementing an integrated, writing program with a basic Algebra II textbook for one semester. The writing program, which was designed by the researcher, consisted of specifically formulated writing lessons designed to enhance students' understanding of topics studied. Two sections of the class were used as an experimental group and two sections were used as the

treatment group. The sixty-eight students were from a private school in the southeastern United States. Writing activities were integrated within the experimental group's lessons. Data collection instruments included tests, writing attitude scales, mathematics attitude scales, and student writing. The results indicated that there was no significant difference between the experimental and control groups in the tests or attitudes, nor were there any differences between the pre- and post-test attitudes of writing or mathematics for either group. A background analysis of the groups helped to explain the stability of these results. Since the experimenter had taught a majority of the students in the prior year, the classroom routine had remained relatively stable. Also, all the students were used to a demanding curriculum that required a great deal of writing. Trends in the data suggested that a longer study might have resulted in the experimental group performing significantly higher than the control group on an achievement measure.

Butkowski (1994) investigated the effects of an experimenter-designed program for developing higher-order thinking skills in mathematics. The five-month study took place in a middle-class suburb of Chicago and involved groups of third-, fifth-, and sixth-grade students. Three interventions were utilized, (1) cooperative learning, (2) instruction in mathematical problem-solving strategies, and (3) curriculum revision with the addition of a mathematical problem-solving program. Students utilized writing through tools that evaluated their daily performance on individual and group tasks and assessed their metacognition. Students also used math journals to reflect on their daily math activities and learning, write mathematical essays, and develop their own problems. The results of this

study were measured through problem-solving pre- and post-tests, student surveys, teacher observation checklists, and student attitude surveys. The results demonstrated that all of the components of the program contributed to student acquisition of mathematical problem-solving strategies, an increase in student confidence levels in mathematics, and an increase in student achievement on non-routine problems requiring higher-order thinking skills. These findings demonstrated that coupling problem-solving strategy instruction with writing increased both mathematical achievement and attitude.

A similar study was conducted by Kjos and Long (1994). The researchers examined the effects of a mathematics intervention that was designed to assist students in creating and accepting divergent thinking in solving mathematical problems. A group of 171 fifth-grade students in two school districts west of Chicago from multicultural communities with varied economic backgrounds were targeted. The students' critical thinking skills were assessed as being underdeveloped by teacher observation, tests, and student surveys at the beginning of the study. An analysis by the researchers of probable cause data showed that students lacked adequate problem-solving strategies, confidence in mathematical abilities, and an inability to communicate their thinking. Previous instruction that the students had received revealed that there was an overemphasis on basic skills and computation with little attention toward higher-order thinking and problem-solving skills. The treatment consisted of an instructional approach that included the direct teaching of problem-solving strategies, the use of manipulatives to enhance mathematical instruction, and the use of writing

to develop metacognitive abilities. After twelve weeks, the students completed a problem-solving post-test. The results showed that students demonstrated an improvement in their confidence in using mathematics and an increased ability to communicate their thinking through writing. The researchers concluded that direct instruction of problem-solving strategies, the use of manipulatives, and the use of writing should be part of any mathematics program.

In another study of elementary mathematics programs, Mastin (1996) determined the effects of two different programs on student learning. Third-grade students from varying socio-economic backgrounds in two rural Minnesota schools were chosen. The students in each school were exposed to a different mathematics program since kindergarten, i.e., a skills-based program and a concept-based program. Data were collected through observations of student learning, journals of student writing, and a standardized test. Quantitative results indicated that both groups learned mathematics skills equally well, but the concept-instructed group performed better than the skill-instructed group in problem-solving. Qualitative results suggested that the skill-instructed group relied on the correct use of computation algorithms in their journal entries. The students utilized words and numbers to express ideas, but did not use inferences to draw conclusions. The concept-instructed class often used mathematical language and prior knowledge to express their ideas and also used inferences to draw conclusions. These findings indicated that students who excelled in utilizing problem-solving were able to express their ideas and take risks in finding solutions through utilizing mathematical language in writing while those

who were weaker in problem-solving skills were happy in finding expected answers using algorithms and numbers.

A study on the effects of improving students' problem-solving abilities through the use of teaching problem-solving strategies was done by Wilborn (1994). The research was conducted in a suburban elementary school in the western United States that had a high percentage of Mexican-American students with limited or no English language skills. Twenty-six third-grade students were chosen. Activities were designed to increase the students' interest and ability in solving word problems. Preliminary student interviews were conducted. Within small cooperative groups, the students were taught how to use open-ended questions and problem-solving strategies. An emphasis was placed on mathematical language development, comprehension of written word problems, and writing. The students wrote, read, and solved original word problems. Observation of students was used to collect data on how the students responded to the various activities. The students written word problems were evaluated regularly and at the end of the study. The results indicated that when students were taught problem-solving strategies and how to read word problems with understanding, the students would enjoy and be successful in solving word problems. As a result of these findings, Wilborn suggested that student writing and reading of word problems improved reading, writing, and mathematical problem-solving abilities.

Miller (1992) conducted a study to investigate the benefits derived by teachers from using impromptu writing prompts in algebra class. The study attempted to determine what teachers could learn about their students'

understanding of school mathematics from reading their written responses to prompts and if instructional practices were influenced as a result of reading students' written responses to prompts. Three teachers from a large metropolitan high school volunteered to participate in designing and implementing an action research plan that would investigate the benefits of writing in secondary mathematics classes. Two first-year algebra classes and one second-year algebra class consisting of seventh-grade , eighth-grade , and ninth-grade students participated in the study. The students varied according to race and socioeconomics, and their academic abilities were described as being average to below average. Impromptu writing prompts were used to foster students' written responses to specific questions or problems. The students had five minutes in which to produce a clear expression of their mathematical understanding. An interpretive research methodology was implemented in the study. Data were collected from the students' written responses and field notes derived from discussions with the teachers during meetings of the research team. The results showed that the teachers' assessment of students' understanding of mathematics was enhanced by the students' responses to writing prompts, and that the teachers in the study believed that their instructional practices were influenced as a result of reading their students' responses to writing prompts. The researcher concluded that teachers better understood the individual learning processes, knowledge, and attitudes of students toward mathematics through reading students' writings about mathematics. Writing in response to prompts also encouraged students to become more proficient at expressing their mathematical ideas in writing and understanding written mathematical

presentation.

In research done by Silver, Shapiro, and Deutsch (1993), about 200 middle school students were given a division-with-remainders problem to solve, and their solution processes and interpretations were examined. The experimenters used semantic-processing models from earlier research to analyze the students' problems. Success or failure in solving the story problems was cited on the basis of the presence or absence of an adequate written interpretation by the student of how the numerical solution was derived. The attempts of the students to make sense of their answers were also analyzed for evidence that supported or refuted the hypothesized semantic-processing models. The results indicated that the models provided evidence of the students' failure to solve division-with-remainder problems in the classroom setting. In addition, the results indicated that student performance was adversely affected by their inability to apply sense making to the solution of school mathematics problems and their difficulty in providing written expressions of their mathematical thinking and reasoning.

Gibisch, Lumpkins, Sewell, and Vagena (1995) studied the effectiveness of a program that was designed to improve students' writing performance across the curriculum. The six-month study involved kindergarten, third-grade, and fourth-grade students from a middle-class suburb of Chicago. Prior to the study, deficiencies in student writing across the curriculum were documented through teacher observations and writing samples. Analysis of the probable cause data revealed that teachers attributed student underachievement in writing to an overloaded curriculum, lack of writing opportunities, and attitudes toward writing. A review of the scholarly literature suggested that

the students were poor writers due to a deficient writing curriculum and attitudes from prior writing experiences. Two interventions were selected, i.e., implementation of a comprehensive writing program and the establishment of a cooperative learning program. The instructional strategies within these programs included the modeling of writing techniques, the use of daily writing journals by students, and the use of writing in all disciplines. At the end of the study student writing and attitudes were evaluated. The data derived from these post-intervention instruments indicated positive attitudes towards writing, improved clarity in students' writing, and increased confidence in editing and revising.

Another study involving writing across the curriculum was conducted by Hillary (1996) to investigate the effects of a teacher inservice training program on student writing skills. Subjects were nine teachers and 200 third- and fourth-grade students in a suburban elementary school. Teachers were trained in the implementation of a writing program that extended into all curricular areas. After twelve weeks of instruction, the student writings and observations of students were analyzed to reveal that 65% of the students showed gains in their abilities to write using realistic situations. Teachers were also surveyed, and their reactions to the integrated curriculum were all positive. Results of the study suggested that integrating writing into the content areas produced critical thinking skills and enhanced students' writing skills.

Hackett and Wilson (1995) studied the effectiveness of an intervention for improving adolescent writing and speaking skills using mathematical language. The targeted population consisted of freshman and sophomore

high school students in a middle- and upper-middle-class suburban community located west of Chicago, Illinois. Teacher observations, student interviews, and teacher-made assessments were used to document the problems of writing and speaking using mathematical language. An analysis of probable cause data revealed that students lacked the basic understanding of mathematics vocabulary, lacked confidence in their mathematical abilities, and lacked the knowledge of math writing skills. The curriculum and previous instruction were reviewed and revealed an over-emphasis on basic skills and computation with minimal attention to writing and speaking using mathematical language. An intervention of increasing the instruction of writing and speaking using mathematical language through the use of journal writing, cooperative learning, and portfolio assessment was selected and implemented for four months. Data were collected from student attitude surveys, teacher observations, and student interviews. The results indicated that students' attitudes toward writing and mathematics had improved, students' understanding of mathematics had improved, and students showed an increase in their ability to talk mathematically.

Other articles that were reviewed were written by authors who had implemented writing programs within mathematics classrooms and had read extensive research and literature that supported writing in mathematics. Kroll and Halaby (1997) encouraged teachers to integrate linguistic and mathematical thinking. Halaby was a second- and third-grade teacher in a laboratory school that had twenty-one students and educated teachers. About 75% of the children were white and from middle-class backgrounds, and the remaining 25% were non-white. Kroll was a college faculty member who was

conducting research about the relationship between children's mathematical learning and their use of the writing process. Math journals, math conferences, and solution sharing were chosen as the means by which mathematical reflections and problem-solving could be developed in the students. The authors cited evidence through reading the students' journals that the children's ability to solve and explain their problem-solving processes with clarity and completeness improved dramatically. The ability to express mathematical thinking and sense making also extended into their oral explanations. The authors also found that the journal entries were valuable assessment tools that followed the problem-solving development of each student.

Another article by Brown (1997) supported the use of journal writing with young children. Math journals were used in a first-grade classroom to promote relevancy. All steps of the writing process were utilized. Students began the process by brainstorming situations outside of school in which the use of mathematics was required. Then, the students wrote about their own experiences in using mathematics outside of the school setting. Each student chose one particular experience around which to write a word problem. The problems were published on index cards for all students to use in problem-solving. The author suggested that the writing program promoted students' discovery of relationships between mathematics studied in school and real-life situations.

Journal keeping in mathematics class was also outlined by Helton (1995). The author suggested that journals were a tool for children to express and document their mathematical thinking. The purposes for using journals

included demonstrating heuristics and practicing skills, creating word problems, and recording and analyzing mathematical thinking. Each approach was described as it was observed by the author in programs developed by two teachers in Florida elementary classrooms. The author found that the use of journals gave the students opportunities to explore mathematical concepts, develop understandings, and analyze and express their thinking. It was suggested that regular conferences with students about their journals, teacher modeling of journal entry writing, and the teacher keeping a journal were important in fostering the success of the program.

**Summary of the Review**

The research relevant to this study had the following implications about using writing with mathematics instruction.

1. Writing had been shown to have significant effects on mathematics achievement, particularly in problem-solving, higher-order thinking skills, and solving word problems.

2. Metacognitive abilities were developed through writing about mathematics, and students became more aware of their own strengths, weaknesses, and learning processes.

3. Students who wrote in mathematics journals became more expressive and thoughtful of mathematics concepts and readily connected prior knowledge with new information.

4. There was a correlation between the use of writing in mathematics and feelings of confidence in both writing and mathematics.

5. Students who wrote regularly in mathematics classes became more

effective communicators in both speaking and writing, and they were able to use mathematical language more effectively.

6. Teachers better understood students' understanding of mathematics through reading their responses to writing prompts, and they could better design instruction to fulfill the learning styles and needs of the students.

The effects of writing on mathematics achievement was consistent among students from primary schooling levels through secondary schooling levels.

## METHODS

The Methods Section contains a description of the sample that was used for the project. Also, included in this section is an explanation of the instruments that were developed and used for the project. Lastly, the procedures that were followed are described.

### Sample

This project was conducted in a school district that was spread along the shoreline of the St. Clair River in southeastern Michigan consisting of two small cities and the six surrounding townships. Demographics information were derived from the 1990 census and district statistics.

According to the 1990 census, the district had a population of approximately 24,698 with a predominance of Caucasians (24,422), and the remaining population listed as either Hispanic (191), Asian and Pacific Islander (49), American Indian, Eskimo, Aleutian (30), and black (6).

The total working population of the communities that comprised the school district was approximately 12,065 (based on 1990 census data) with approximately 5,546 considered to be white collar jobs, approximately 6,264 in blue collar jobs, and approximately 255 in the farming, forestry, and fishing industries. White collar workers were predominately professional, managerial, technical, sales, and administrative support workers. Blue collar workers were employed predominately by service, manufacturing, and transportation industries. The median household income was $33,064. The

median housing value was $69,936.

The school where this project took place was in a district which covered approximately 122 square miles. The district facilities included six elementary schools (grades K to five), two middle schools (grades six to eight), two high schools (grades nine to twelve), and one adult education center. According to the school districts' records, the student population was approximately 5,300. Racially, 99% were white and 1% were Hispanic.

The total population of the elementary school where the project was conducted was 556. The total second-grade population of the project elementary school was 120 students. The twenty-one students of the second-grade project group represented approximately 3% of the total school population. Approximately 75% of the students' parents were in the blue collar work force. The project group was 91% white and 9% Hispanic. The students were in a self-contained classroom with all subjects taught by the Project Director. The students were considered to be of below-average to above-average intelligence. The nine girls and twelve boys ranged from seven- to eight-years-old. The students were from 86% intact families with 14% in single parent households.

## Instruments

A total of three instruments were used to gather data for this project. The instruments were the Card Mathematical Problem-Solving Assessment for Second Grade (CMPSASG), a post-project Writing in Mathematics Interview to Determine Metacognition (WMIDM), and a Project Director's journal.

The CMPSASG (see Appendix A, pp. 62 to 64) was designed by the Project

Director to gather data about the students' abilities to solve mathematical word problems. It consisted of three word problems that required the students to employ precise algorithms and utilize mathematical language in solving the problems. A fourth problem asked the students to devise and write a word problem that could be solved by another student. A rubric was used to score the assessment with each problem outlined with characteristics that were required in the written response of the student. A "yes" or "no" box was checked to indicate whether or not particular evidence was cited in the response of the student. For those students whose final score was twelve to fourteen, effective communication of mathematical thinking and reasoning through writing was prevalent. For those students whose final score was nine to eleven, some evidence of mathematical thinking in writing was prevalent. For those students whose final score was zero to eight, difficulty with expressing mathematical thinking through writing was prevalent. This instrument was given to the sample group during the week prior to the project and on the last day of the seven-week project.

The instrument had been reviewed for appropriateness by Master's level colleagues who had expertise in instrument development. A pilot study was also conducted and further supported the appropriateness of the instrument. The twenty second-grade students that participated in the pilot study indicated that they had no difficulty understanding the directions or word problem texts. The administration of the assessment took about thirty minutes, with the students reading and writing their responses.

The post-project WMIDM (see Appendix B, pp. 65 to 66 ) was designed by the Project Director to obtain information on students' mathematical

metacognition at the end of the project. This five question, post-project interview had also been reviewed for appropriateness by Masters'-level colleagues who had expertise in instrument development. The twenty second-grade students who pilot studied the CMPSASG also pilot studied the post-project interview. They indicated that they had no difficulty understanding any of the interview questions.

Informal observation were recorded in the Project Director's journal. The journal kept an ongoing record of the project on a day to day basis. It was designed to record observations and gather information reflecting performance, individual differences and similarities in processing mathematical thinking, attitudes, and interest that could not be obtained using either of the other instruments utilized for the project.

**Procedures**

Five days before the project began, the Project Director administered the CMPSASG in order to assess the abilities of the students in solving mathematical word problems with written responses. The students received thirty minutes to complete the assessment. The project was conducted five days per week for seven weeks.

The Project Director provided each student with a blank, spiral-bound notebook to be used as a mathematics journal for the duration of the project. Writing prompts were designed to extend daily mathematics lessons and activities. The students responded to the writing prompts in their journals. The Project Director provided oral feedback daily to each student after reading or listening to the students' responses. The students were also given

opportunities to read their journals aloud to the rest of the students on a daily basis if they chose. An area in the classroom was established with a table, chairs, and writing supplies for students to write during their spare time or free-choice time. A place value unit of instruction based on lessons and activities from Math by all Means: Place Value, Grade 2 (Burns, 1994) was started on the first day of the project. The daily lessons, activities, and writing prompts for the seven-week project were as follows:

I. **Week One**

A. **Day One**: Math Journal Introduction and Place Value Unit

1. Journals were given to students with instructions about their purpose.
2. Students were given an introduction to place value through an exploration with base-ten blocks.
3. Writing prompt: What is place value?

B. **Day Two**: Building a 0-99 Chart

1. A class 0-99 chart was constructed as a whole-group.
2. Writing prompt: Describe how a 0-99 chart is built.

C. **Day Three**: 0-99 Chart Review and Use With Addition

1. The 0-99 chart arrangement of numbers was discussed.
2. The Project Director modeled a way to use the 0-99 chart to add numbers.
3. Writing Prompt: How can the 0-99 chart be used to solve this problem: If I had 39 pencils yesterday and I got 12 more today, how many do I have now?

D. **Day Four**: Journal Response Sharing and "Stars in One Minute"

1. The students shared their responses to the writing prompt from the previous day.
2. A game, "Stars in One Minute" (Burns, 1994) was introduced and practiced.
3. Writing prompt: Describe how to play "Stars in One Minute."

E. **Day Five**: "Stars in One Minute" Practice and Graphing

1. The students practiced playing "Stars in One Minute."
2. The class made a graph using data comprised of the different methods by which the students counted their stars.
3. Writing prompt: Describe the two ways that you used to count your stars.

II. **Week Two**

A. **Day One**: Math Game Introductions

1. Three math games were introduced: "Race for $1.00," "Dollar Signs," and "Cover a Flat" (Burns, 1994).
2. The students practiced all three games with partners.
3. Writing prompt: What is your favorite game, how is it played, and how does it help you to learn about math?

B. **Day Two**: Math Game Practice

1. The students practiced the games that were introduced on the previous day.
2. Writing prompt: What is your second favorite game, how is it played, and how does it help you to learn about math?

C. **Day Three**: 0-99 Chart Pattern Investigations

1. The Project Director gave the students a rule: All the two-digit

numbers on the chart that have both digits the same.

2. The students guessed numbers that fit the rule and noted a pattern that had occurred on the chart.
3. Writing prompt: Write two rules that can be used with the 0-99 chart and describe what each pattern would look like.

D. **Day Four**: "Guess My Rule" (Burns, 1994) Introduction and Practice

1. The students were taught how to play "Guess My Rule."
2. Writing prompt: What is a pattern?

E. **Day Five**: "0-99 Patterns" (Burns, 1994) and Homework Assignment

1. The "0-99 Patterns" game was introduced.
2. Students worked on all games that have been introduced previously.
3. "The Go Around Dollar" (Adams, 1992) was read and discussed.
4. Homework Assignment: Teach someone at home how to play "Race for $1.00."
5. Writing Prompt: What did you learn about math from the story "The Go Around Dollar"?

III. **Week Three** (The project was conducted for four days this week.)

B. **Day One**: "Number Puzzle" (Burns, 1994) Introduction

1. The students reported on their experiences playing "Race for $1.00 at home.
2. The students were taught how to make "Number Puzzles."
3. The students were given time to practice the games and activities previously introduced that they wanted to play.
4. Writing prompt: Describe how you made your number puzzle.

C. **Day Two**: "Counting Fish" (Burns, 1992) Lesson

1. Each child was asked to put two interlocking cubes (fish) into a class bucket.
2. Writing prompt: How many fish are in the bowl, and how did you figure out your solution?
3. Free-choice time was provided for students to practice any previously introduced math games and activities.

D. **Day Three**: "Counting Fish" Continued

1. The students shared their written responses from the previous day.
2. The cubes in the bucket were counted in various ways, grouping them by 2s, 5s, and 10s.
3. Writing prompt: What way did you feel was the best way to count the fish?
4. Free-choice time was provided for the students to practice any previously introduced math games and activities.

E. **Day Four**: Assessment and Homework Assignment

1. The student were given the following assessment question with which to respond in their journals: "Write about the number of 10s and 1s there are in the total number of fish in the bowl."
2. Free-choice time was provided for the students to practice any previously introduced math games and activities.
3. The following homework assignment was given: Teach someone at home how to play "Dollar Signs."

IV. **Week Four**

A. **Day One**: "Fill the Cubes" and "Make a Shape" (Burns 1994)
   1. The students shared their experiences with playing "Dollar Signs" at home.
   2. The students were taught how to play "Fill the Cubes" and "Make a Shape" and given time to practice.
   3. Writing prompt: Which game was your favorite, why was it your favorite, and how did it help you to learn about math?

B. **Day Two**: "Fill the Cubes" and "Make a Shape" Practice
   1. The students practiced playing "Fill the Cubes" and "Make a Shape."
   2. Writing prompt: Write about the game that you did not choose to write about yesterday. Tell how it helps you to learn about math.

C. **Day Three**: "Stars in One Minute" Graph Revisited
   1. The students reviewed and discussed the class graph that was created previously with data from playing "Stars in One Minute."
   2. The students were asked to write five generalizations about the data displayed on the graph in their journals.
   3. The generalizations were shared and a class list was made.
   4. Time was given to play chosen games and activities that had been previously taught.

D. **Day Four**: Tens and Ones
   1. The Project Director led the students in identifying the number of tens and ones that were in numbers chosen from the 0-99 chart.

2. The students completed a worksheet that required them to write a number based on clues given about the digits or values in the tens and ones places.
3. Writing prompt: How are the tens and ones places different?
4. The following homework assignment was given: Teach someone at home how to play "Number Puzzles."

E. **Day Five**: "Five Tower Game" and "Guess My Number" (Burns, 1994)

1. The students reported on their experiences at home playing "Number Puzzles."
2. The students were taught how to play "Five Tower Game" and "Guess My Number."
3. The students practiced the games.
4. Writing prompt: Which game was your favorite, why was it your favorite, and how did it help you to learn about math?

V. **Week Five**

A. **Day One**: Practice of Games

1. The students practiced the games from the entire unit of study.
2. As a whole-group, the class discussed which games were favorites and how all the games related to learning about groups of numbers and place value.
3. Writing prompts: What is place value?

B. **Day Two**: Written Assessment

1. The students shared their journal responses from the previous day.

2. The following problem was given as an assessment of the students' learning: "Catherine had two piles of beans: one with 49 beans and one with 17 beans. How can she figure out how many beans she had altogether?"
3. The students were asked to teach someone at home how to play "Guess My Number" as homework.

C. **Day Three**: The King's Commissioners (Friedman, 1994)

1. The students read and discussed their solutions to the problem from the previous day.
2. The students discussed their experiences at home playing "Guess My Number."
3. The Project Director read The King's Commissioners.
4. The students described the counting systems that were used as the plot of the book in their journals.

D. **Day Four**: More reflection on The King's Commissioners

1. The students discussed other commissioners that might be appointed and how many the king would need.
2. The students were given a three-part writing assignment. First, the students had to explain one of the ways to prove that the First Royal Advisor in the story was correct. Second, the students had to prove how the Second Royal Advisor was correct. Third, the students had to prove how the princess was correct.
3. The students played place value games taught previously.

E. **Day Five**: Problem-solving

1. The students were given the following problem to solve in their journals: "Two children were playing 'Cover a Flat.' One had covered 28 squares on her hundreds square; the other had covered 35 squares. If they put all of their blocks together on one flat, how many squares would they cover?" The students were reminded to describe their thinking and how they solved the problem.
2. The students played the place value games that were taught previously.

VI. **Week Six**

A. **Day One**: "Race for a Flat" (Burns and Tank, 1988)

1. The students were taught how to play "Race for a Flat" which involved rolling dice to gain base-ten block cubes in efforts to eventually have enough to trade for rods and finally a flat.
2. The students wrote about how the game "Race for a Flat" helped them learn about place value.

B. **Day Two**: Using Base-ten Blocks

1. The students played "Race for a Flat."
2. The class discussed how it is possible to represent a two-digit number with many different combinations of base-ten blocks.
3. In their journals, the students described the ways possible that they could make 50 using base-ten blocks.

C. **Day Three**: Base-ten Riddles

1. The students were taught how to write base-ten riddles. Example: "I am made up of two rods and 5 cubes. What am I?"

2. The students wrote their own original riddles in their journals.

D. **Day Four**: Addition with Interlocking Cubes

1. The Project Director demonstrated how to show addition with and without regrouping using interlocking cubes.
2. The students practiced adding numbers provided by the Project Director using interlocking cubes.
3. In their journals, the students described how they add two-digit numbers.

E. **Day Five**: Addition and Subtraction with Interlocking Cubes

1. The students practiced adding two-digit numbers with interlocking cubes.
2. The Project Director demonstrated the ways of using interlocking cubes to subtract two-digit numbers.
3. The students practiced subtracting using interlocking cubes using number problems given by the Project Director.
4. In their journals, the students described how they subtract two-digit numbers.

VII. **Week Seven**

A. **Day One**: Writing Number and Word Problems

1. The students created two-digit addition and subtraction problems. Then, they solved the problems using interlocking cubes.
2. The Project Director demonstrated how to write a word problem involving addition and subtraction of two-digit numbers using real-life situations.

3. In their journals, the students wrote original word problems that could be solved by other students.

B. **Day Two**: Solving Word Problems

1. The students shared their word problems with partners who solved the problems.
2. The students were given some word problems to solve using interlocking cubes or algorithms.
3. The students wrote more original word problems involving two-digit addition and subtraction in their journals.

C. **Day Three**: Solving Word Problems

1. The class discussed ways to solve word problems.
2. The students were given a list of word problems to solve.
3. In their journals, the students described how they solved word problems.

D. **Day Four**: Publishing Word Problems

1. The students chose favorite word problems from their journals and published them on index cards.
2. The Project Director demonstrated the algorithms for adding two-digit numbers with regrouping and without regrouping.
3. The students completed a worksheet involving the addition of two-digit numbers with regrouping and without regrouping.

E. **Day Five**: Word Problem Exchange and Assessment

1. The students completed the CMPSASG.
2. The students exchanged published word problems from the previous day to solve in writing in their journals.

3. The Project Director conducted individual interviews using the WMIDM.

## RESULTS

The project results are displayed in a table and a narrative summary that consists of the post-project WMIDM results and the anecdotal records from the Project Director's journal. Table 1 has been created to display the pre- and post-test results from the CMPSASG.

Table 1 shows the results from the Card Mathematical Problem-Solving Assessment for Second-Grade. Each student in the sample is represented by a letter of the alphabet in the first column. The students' scores from the test administration at the beginning of the project are listed in the second column. The students' scores from the test administration at the end of the project are listed in the third column. The percentages of change between the beginning scores and ending scores are shown in the fourth column. There are fourteen possible total points that can be earned on the CMPSASG as determined through the use of a rubric.

The interview responses of the Writing in Mathematics Interview to Determine Metacognition are listed exactly as they were articulated by the students. All twenty-one of the sample students have been asked five post-project interview questions. Each student in the sample is represented by a letter of the alphabet. The students' responses are listed after the questions that have been asked.

The journal summary describes informal observations the Project Director has made in the project journal throughout the seven-week project. The anecdotal records are shown in narrative form.

## Table

Table 1 - Results from the Card Mathematical Problem-Solving Assessment for Second-Grade

| Student | Beginning Score | Ending Score | Percentage of Change |
|---|---|---|---|
| A | 2 | 14 | +86% |
| B | 6 | 14 | +57% |
| C | 0 | 14 | +100% |
| D | 8 | 14 | +43% |
| E | 4 | 14 | +71% |
| F | 14 | 14 | 0% |
| G | 5 | 8 | +38% |
| H | 3 | 14 | +79% |
| I | 2 | 14 | +85% |
| J | 0 | 14 | +100% |
| K | 10 | 14 | +29% |
| L | 11 | 14 | +21% |
| M | 5 | 12 | +58% |
| N | 9 | 14 | +36% |
| O | 3 | 10 | +70% |
| P | 7 | 14 | +50% |
| Q | 0 | 11 | +100% |
| R | 0 | 14 | +100% |
| S | 3 | 3 | 0% |
| T | 7 | 6 | -14% |
| U | 4 | 14 | +71% |

Table 1 displays the results of the students' abilities to solve mathematical word problems using algorithms and mathematical language. The data indicate that all but three students have improved on the test after writing

about mathematics daily. One of the students who has shown no improvement has earned the highest number of points possible on both the beginning and ending tests. Only one student has earned the highest number of possible points on the beginning test, and a majority of the students have earned the highest number of possible points on the ending test. There is a drastic change in scores from the beginning test to the ending test. Eleven of the twenty-one students' scores have increased by over fifty percent from the beginning test to the ending test.

**Interview Results**

The results from the post-project interview are based on the responses of the twenty-one students from the sample. Each student has been interviewed separately. The students have been asked to answer each of the following questions in complete sentences and explain and support each answer with a reason.

For question one, the Project Director has asked, "Does writing help you to understand what you are learning? Why?" All twenty-one students have responded positively to this question. Their comments are as follows:

Student A "Yes, it helps me with thinking."

Student B "Yes, you learn more words when you write."

Student C "Sort of. It help me to understand. When I used to do math I didn't understand. It help me think."

Student D "Yes, I don't know why."

Student E "Yes, because I think more in my head."

Student F "Yes, because writing and story problems are alike and it helps

me find an easier way."

Student G "Yes, it just help me."

Student H "Yes, it helps me understand how to read more words."

Student I "Yes, because when I write it helps me know numbers and ones, tens, and hundreds."

Student J "Yes, sort of. It helps me think better."

Student K "Kind of. When other people read their journals, it helped me understand."

Student L "Yes, because you are writing what you think. Sometimes when you do it in your head you forget the answer or what you are doing."

Student M "Sometimes. I don't know why."

Student N "Yes, if I don't know the right answer, hearing other people's answers from their journals helps me find an easier way."

Student O "Kind of. I don't know why."

Student P "Sometimes. I don't know why."

Student Q "Yes, it makes me smarter."

Student R "Yes, it makes it easy to explain."

Student S "Yes, you get to learn more stuff."

Student T "Yes, it helps me think things out."

Student U "Yes, I don't know why."

For question two, the Project Director has asked, "Has your thinking improved in math since you have been writing? How?" All of the students have responded positively to the question. The responses are as follows:

Student A "Yes, I know more things. I've been learning a lot."

Student B "Yes, I try out different words."

Student C "Yes, writing helps me practice in my head."

Student D "Yes, when I write about math it makes me think more."

Student E "Yes, by making me think in my head."

Student F "Yes, it has been improving because to write you need to know the words before you write them so you think about them."

Student G "Yes, it has improved because the math is getting harder."

Student H "Yes, I get better and better at thinking when I do math."

Student I "Yes, when I write my mind is blank so I can picture things in my head."

Student J "I think a lot better than before."

Student K "Yes, I think more about how to solve problems."

Student L "Yes, because writing my thoughts on paper helps me think better."

Student M "Yes, by writing a lot."

Student N "Yes, I'm learning new strategies."

Student O "Yes, I think more."

Student P "Yes, because you write things down and it helps you think."

Student Q "Yes, I think better."

Student R "I'm getting used to it and it helps me figure out math problems."

Student S "I think better."

Student T "Yes, I think more."

Student U "Yes, I'm taking more time."

For question three, the Project Director has asked, "How do you now solve

a math story problem?" All of the students have responded with the description of a strategy. The responses are as follows:

Student A "I think about it."

Student B "You think of it as a story."

Student C "I connect the words with numbers."

Student D "I get the numbers in my head and figure out the answer."

Student E "I write things down."

Student F "It is pretty easy because I have been doing story problems a lot. All I have to do is think a little."

Student G "I look at it ten times and I finally get it in my head."

Student H "It depends if it is a plus or a minus problem. I think about which one it is."

Student I "I make my head go blank so I can think about the problem and figure it out."

Student J "I think about it after I read it for a little bit. Then, I realize the numbers."

Student K "I think why an answer makes sense."

Student L "I now write the problem on paper and go through the steps to solve and find the answer."

Student M "I think about how the problem should be solved."

Student N "I play with it in my head and figure it out."

Student O "I think and count."

Student P "I read the math problem and then I add or subtract and carry if I need to."

Student Q "I sit there and think."

Student R "I read the problem and add or subtract in my head."

Student S "I think about the words in my head."

Student T "I think of the words and come up with an answer."

Student U "Read and guess the answer."

For question four, the Project Director has asked, "What happens in your mind as you begin to solve a math story problem?" All of the students have responded with strategies. The responses are as follows:

Student A "I look for addition or subtraction."

Student B "I think of each sentence by itself, slowly."

Student C "Step by step, thinking to remember."

Student D "I think about the problem."

Student E "I count backwards or forwards."

Student F "First I clear my mind. Then, I get a problem in my head and it keeps repeating over and over until I figure out the answer."

Student G "I get the problem in my head and I keep thinking about it."

Student H "I do it and I get the answer and I question it to see if I got the right answer."

Student I "My mind goes blank."

Student J "First, I don't get it. But, then I look at it awhile and I get it."

Student K "I would think about what the numbers are and how to solve it."

Student L "I think hard about the answer and nothing else."

Student M "I think about the answer, and then I write it down."

Student N "It starts to develop and I use strategies."

Student O "I see it as a story."

Student P "When I read it, my mind tells me the right answer."

Student Q "I think."

Student R "Think about it."

Student S "I try to think about it."

Student T "I read the problem over."

Student U "I keep trying until I get the right answer."

For question five, the Project Director has asked, "What do you learn when you use writing with math?" All of the students have responded by citing a cognitive process. The responses are as follows:

Student A "How I think."

Student B "I learn what I am good at and what I am not so good at. I know what I know."

Student C "I learn how to do math."

Student D "I learn math better by writing story problems. It helps me think."

Student E "Thinking."

Student F "I learn how to do math because I write a lot about it and it gets easier."

Student G "I learn how to do harder math."

Student H "Writing helps me think more about math."

Student I "I learn more by looking at words and thinking."

Student J "I think a lot more than last year."

Student K "I learn to think and it helps me."

Student L "I learn more about writing and math at the same time. It helps me get better at math because I'm thinking more about the

problem."

Student M "I learn how to count and get the right answer."

Student N "I learn how to do math better."

Student O "I learn to remember."

Student P "I learn to figure out problems by writing words down."

Student Q "I learn to think about math."

Student R "I learn how to think. Thinking takes a lot of time."

Student S "It is easier than it was before."

Student T "I learn how to think better."

Student U "I learn to figure out things in my head."

The students have responded positively to all of the questions. All of the students have been able to cite strategies and reasons that support the use of writing in mathematics. Evidence of metacognition has been present in each of the interviews.

**Journal Summary**

During the seven-week project the Project Director kept a journal, or anecdotal record, about the students and the project five times per week. The Project Director observed that at the beginning of the project, the students' responses to writing prompts in mathematics averaged about three sentences in length. Also, many students asked the Project Director for assistance in writing their responses. Near the end of the project, the students wrote an average of six sentences in response to writing prompts without anyone seeking assistance from the Project Director.

The Project Director also observed the students increasingly and accurately

utilizing mathematical language in writing and speaking as the project progressed. Some words used by students included "addition," "subtraction," "regrouping," "strategy," "minus," "plus," "equals," and "sum." More students were noted using mathematical language near the end of the project than at the beginning. Student generated discussions about mathematics were also observed.

After the Project Director provided instruction on writing and solving story problems, the Project Director observed students writing their own mathematics story problems during their free time without encouragement or discouragement from the Project Director. The students seemed to be excited about creating original story problems involving people in the classroom because many of their problems included the names and interests of fellow classmates. The Project Director noted that there was equal pleasure shown by the students in both writing the mathematical story problems as well as solving the problems.

The Project Director observed that students who possessed weak logical-mathematical skills were on the average just as able to express their ideas about mathematics as students who had strong logical-mathematical skills. Students who were linguistic high achievers could even better express their mathematical ideas in writing. Students with both logical-mathematical and linguistic strengths were the most descriptive and expressive in their responses. The assessment of the students' strengths were based on prior tests and observations conducted by the Project Director during the five months prior to the project.

Students were observed by the Project Director as describing their

mathematical thinking sequentially. When asked by the Project Director to solve word and number problems, many students used sentences beginning with "first," "then," and "next" in explaining processes. Students seemed concerned with understanding processes and concepts in addition to knowing correct answers. The Project Director also noted that the students had individual strategies for solving mathematical problems despite having the same prior instruction involving mathematical strategies and algorithms. The difference in approaches to mathematical problems and concepts was evidenced in the students' written responses. Very few children demonstrated the exact same process for solving or responding to any one particular story problem or writing prompt.

## CONCLUSIONS AND RECOMMENDATIONS

This project was conducted over a seven-week period to examine the levels of achievement and metacognition in expressing mathematics understanding and problem-solving processes by students in a second-grade classroom. Many researchers supported the idea that mathematical thinking and problem-solving skills were necessary for understanding mathematics. Writing was cited as the means by which mathematical thinking and problem-solving strategies could be developed and expressed. Researchers found that writing about mathematics was an effective way to improve students' metacognition, conceptual understanding, communication, and problem-solving skills related to mathematics. Math journals, writing prompts, and student-written word problems were cited as activities to support writing in mathematics.

Twenty-one second-grade students participated in the project as the sample. At the beginning the students were given a mathematics problem-solving achievement pre-test, and at the end the students completed a mathematics problem-solving post-test and participated in five-question individual student interviews to determine metacogntion. The Project Director maintained anecdotal records in the form of a journal throughout the project.

During the project, the sample group was given daily writing prompts with which to respond in mathematics journals. The writing prompts were designed to elicit student thinking about mathematical concepts, problem-

solving, and word problem development. The students wrote after a mathematics lesson or hands-on activity. Opportunities for sharing written responses and word problems were provided to the students almost every day. Student-written word problems were exchanged for other students in the classroom to solve.

After completing the project and reviewing the results of each of the instruments, the following conclusions and recommendations were made by the Project Director.

## Conclusions

The following conclusions were made by the Project Director based on an analysis of the results of the seven-week project conducted to examine the levels of achievement and metacognition in expressing mathematical understanding and problem-solving processes by students in a second-grade classroom.

1. Students' mathematical understanding and problem-solving achievement greatly increased. It would seem that the daily writing activities utilized in the classroom contributed to the change in mathematical conceptual understanding and problem-solving abilities.
2. The students felt that their understanding during learning activities was improved by writing. It would seem that teachers should integrate writing into all curricular areas to enhance and improve learning.
3. The students responded positively to the idea that writing improved their thinking in mathematics. It would seem that teachers should utilize writing during mathematics instruction to enhance students' thinking.

4. Not all students increased their achievement levels in mathematics. It would seem that teachers should find and utilize other methods of instruction to improve achievement for all students.

5. The students were able to articulate their individual thinking processes about mathematics. It would seem that writing contributes to students' abilities to describe and analyze their own thinking through using metacognition.

6. Students described personal strategies for solving mathematics word problems that were unique to each individual. It would seem that teachers should instruct in a variety of strategies in mathematics and use students' written responses to become aware of students' personal strategies.

7. When writing supplies were readily available within the classroom, students chose to write mathematics word problems in their spare time. It would seem that teachers should provide a variety of writing supplies for students to use during their extra time to write mathematics word problems.

8. The students' use of mathematical language in both writing and speaking increased. It would seem that by immersing children in an environment with interactions involving reading, writing, and speaking enables students to learn to use language and communicate in meaningful ways.

9. Students' original mathematics word problems focused on their personal experiences or members of the classroom. It would seem that the personal world of the learner facilitates the learning process as concepts are secured in spatial memory.

**Recommendations**

The following recommendations are based on the conclusions of the project regarding the levels of achievement and metacognition in expressing mathematics understanding and problem-solving processes by second-grade students.

1. Teachers need to consider their students' individual thinking processes when planning mathematics lessons. Using writing in mathematics can be an effective way for both students and teachers to gain insight in students' ways of thinking.

2. A variety of instructional methods need to be used in mathematics in order to meet the needs of all students. Integrating writing with other mathematics activities may provide the necessary variety to individualize instruction.

3. Both writing and sharing writing with others is important to develop mathematical language and a variety of problem-solving strategies. Providing writing experiences on a regular basis can help develop mathematics language, skills, and concepts.

4. A variety of writing supplies needs to be available to students for writing. By having writing instruments and paper available, students who have additional work time will be able to write mathematics word problems and share with others in solving. Other students may develop mathematics skills and strategies by using the writing supplies.

5. By providing writing prompts about mathematics concepts on a regular basis, teachers help develop students' metacognitive thinking. Teaching students to understand and analyze their thinking can help improve

mathematics achievement.

6. Students' real-life experiences, the sharing of writing, and discussions about mathematics need to be promoted by teachers in the classroom context. The natural connections that students make between their understandings of the world and mathematics skills and concepts can help them to actively process information.

The purpose of this project was to examine the levels of achievement and metacognition in expressing mathematics understanding and problem-solving processes by students in a second-grade classroom. Through daily writing activities involving expressing mathematics thinking, problem-solving, and the creation of word problems, students' mathematics achievement and metacognition increased. Teachers should utilize writing in mathematics instruction as well as other curricular areas in order to promote and extend thinking and learning. When teachers would provide students with writing experiences that foster reflections and analyses about knowledge, they would be promoting habits in students that may contribute to a lifetime of meaningful learning.

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# Appendix A

# Card Mathematical Problem-Solving Assessment for Second-Grade

Directions: Provide a copy of each of the following problems on separate sheet of paper for each student. The student must read each problem and answer each in writing on a piece of lined paper (one per problem).

## Problems

1. Tell how many 10s and 1s there are in 68. Explain why your answer makes sense.

2. Solve this problem: There are 36 peanuts in a dish yesterday. 15 are added today. How many peanuts are in the dish now.

3. Emily counted 49 shells, and then she counted 17 more. How many did she have altogether.

4. Write a math story problem that another person could solve.

# Card Mathematical Problem-Solving Assessment Rubric

Directions: Use the appropriate rubric to assess the components of the student's written response. Add the number of checks in the yes column to determine the score.

| Question #1 | Yes | No |
|---|---|---|
| 1. Thinking and reasoning is evident. | | |
| 2. There is evidence of understanding of the math concept. | | |
| 3. The student's unique/individual way to solve the problem was described and expressed. | | |

| Question #2 | | |
|---|---|---|
| 1. Knowledge of the correct algorithm is evident. | | |
| 2. Thinking and reasoning is evident. | | |
| 3. There is evidence of understanding of the math concept. | | |
| 4. The student's unique/individual way to solve the problem was described and expressed. | | |

| Question #3 | | |
|---|---|---|
| 1. Knowledge of the correct algorithm is evident. | | |
| 2. Thinking and reasoning is evident. | | |
| 3. There is evidence of understanding of the math concept. | | |
| 4. The student's unique/individual way to solve the problem was described and expressed. | | |

| Question #4 | | |
|---|---|---|
| 1. The problem is written in a logical, sequential manner. | | |
| 2. Knowledge of the required operation is evident through the components of the problem. | | |
| 3. There is evidence of understanding of the math concept. | | |

12-14 Understands mathematical concepts. Effective communication of mathematical thinking and reasoning shown.
9-11 Understands concepts somewhat. Some evidence of mathematical thinking shown, but not complete.
below 9 Difficulty understanding concepts and expressing mathematical thinking.

# Writing in Mathematics Class
# Individual Student Interview to Determine Metacognition

Directions: Read each question to the student and record the responses on lined-paper.

1. Does writing help you to understand what you are learning? Why?

2. Has your thinking improved in math since you have been writing? How?

3. How do you now solve a math story problem?

4. What happens in your mind as you begin to solve a math story problem.

5. What do you learn when you use writing with math?

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