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Writing in the Mathematics Classroom

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WRITING IN THE MATHEMATICS CLASSROOM

BY

RYAN C. GHERE

THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF ARTS IN MATHEMATICS

IN THE GRADUATE SCHOOL, EASTERN ILLINOIS UNIVERSITY
CHARLESTON, ILLINOIS

2000

I HEREBY RECOMMEND THIS THESIS BE ACCEPTED AS FULFILLING THIS PART OF THE GRADUATED DEGREE CITED ABOVE

July 14, 2000
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ABSTRACT

This paper explores the benefits of using writing as a tool for teaching mathematics. It is a summary of literature intended to help educators implement a writing plan of their own. Part one is a summary of the purpose, benefits, and types of mathematics writing. Writing in mathematics opens the lines of communication in the classroom, helps in assessment, and allows for the use of interdisciplinary units. Writing in mathematics benefits students, teachers, and the classroom learning atmosphere as a whole. Teachers can use informal writing assignments so that students express their opinions, or assign formal writing to provide students with an opportunity to write about mathematical topics. Part two of this paper is a comparison of the effects of writing in a pre-algebra classroom. One class was the control group and did no writing, one class kept a mathematics journal, and another was asked to answer open-ended questions on a regular basis. Data is included that supports claims that writing in mathematics reduces math anxiety and assists students in learning mathematics. The purpose of this paper is to provide educators with ideas of how to implement a writing program in their classrooms.
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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>ii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>TABLES</td>
<td>vi</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>1 WRITING IN MATHEMATICS</td>
<td>1</td>
</tr>
<tr>
<td>2 MATH ANXIETY</td>
<td>5</td>
</tr>
<tr>
<td>Causes of Math Anxiety</td>
<td></td>
</tr>
<tr>
<td>Solutions</td>
<td></td>
</tr>
<tr>
<td>3 PURPOSE OF WRITING IN MATHEMATICS</td>
<td>8</td>
</tr>
<tr>
<td>Open Lines of Communication</td>
<td></td>
</tr>
<tr>
<td>Student Assessment</td>
<td></td>
</tr>
<tr>
<td>Interdisciplinary Units</td>
<td></td>
</tr>
<tr>
<td>4 BENEFITS OF WRITING</td>
<td>11</td>
</tr>
<tr>
<td>Student Benefits</td>
<td></td>
</tr>
<tr>
<td>Teacher Benefits</td>
<td></td>
</tr>
<tr>
<td>Classroom Benefits</td>
<td></td>
</tr>
<tr>
<td>5 MATHEMATICS JOURNALS</td>
<td>17</td>
</tr>
<tr>
<td>Purpose of Journals</td>
<td></td>
</tr>
<tr>
<td>Implementation of Journal Writing</td>
<td></td>
</tr>
<tr>
<td>Benefits of Using Journals</td>
<td></td>
</tr>
<tr>
<td>Assessment</td>
<td></td>
</tr>
<tr>
<td>Learning through Journals</td>
<td></td>
</tr>
<tr>
<td>Making Connections</td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td></td>
</tr>
<tr>
<td>Self-Assessment</td>
<td></td>
</tr>
<tr>
<td>Teaching Tips for Journals</td>
<td></td>
</tr>
<tr>
<td>Grading vs. Not Grading</td>
<td></td>
</tr>
<tr>
<td>Chapter</td>
<td>Title</td>
</tr>
<tr>
<td>---------</td>
<td>--------------------------------------------------------------</td>
</tr>
<tr>
<td>6</td>
<td>OTHER TYPES OF INFORMAL WRITING</td>
</tr>
<tr>
<td></td>
<td>Mathematical Autobiographies</td>
</tr>
<tr>
<td></td>
<td>Learning Logs</td>
</tr>
<tr>
<td></td>
<td>Free-Writing</td>
</tr>
<tr>
<td></td>
<td>Posters and Displays</td>
</tr>
<tr>
<td></td>
<td>Letters</td>
</tr>
<tr>
<td></td>
<td>Creative Writing</td>
</tr>
<tr>
<td></td>
<td>Summary</td>
</tr>
<tr>
<td>7</td>
<td>FORMAL WRITING</td>
</tr>
<tr>
<td></td>
<td>Open-Ended Questions</td>
</tr>
<tr>
<td></td>
<td>Formal Papers</td>
</tr>
<tr>
<td></td>
<td>Student Authored Textbooks</td>
</tr>
<tr>
<td></td>
<td>Question Writing</td>
</tr>
<tr>
<td></td>
<td>Note Taking</td>
</tr>
<tr>
<td>8</td>
<td>WRITING IN MATHEMATICS: A COMPARISON</td>
</tr>
<tr>
<td></td>
<td>Pre-tests</td>
</tr>
<tr>
<td></td>
<td>The Writing Process</td>
</tr>
<tr>
<td>9</td>
<td>MATHEMATICAL AUTOBIOGRAPHIES: AN INTRODUCTION TO WRITING IN THE MATHEMATIC CLASSROOM</td>
</tr>
<tr>
<td>10</td>
<td>JOURNAL WRITING</td>
</tr>
<tr>
<td>11</td>
<td>SOLVING OPEN-ENDED QUESTIONS</td>
</tr>
<tr>
<td>12</td>
<td>COMPARISON RESULTS</td>
</tr>
<tr>
<td></td>
<td>Anxiety Test</td>
</tr>
<tr>
<td></td>
<td>Open-Ended Questions</td>
</tr>
<tr>
<td></td>
<td>Final Exam Scores</td>
</tr>
<tr>
<td></td>
<td>Final thoughts</td>
</tr>
<tr>
<td>APPENDIX A:</td>
<td>JOURNAL WRITING PROMPTS</td>
</tr>
<tr>
<td>APPENDIX B:</td>
<td>OPEN-ENDED QUESTIONS</td>
</tr>
<tr>
<td>BIBLIOGRAPHY</td>
<td></td>
</tr>
</tbody>
</table>
TABLES

1 MATH ANXIETY QUESTIONNAIRE ........................................... 44
2 OPEN-ENDED QUESTION SCORING RUBRIC ................................. 45
3 MATH ANXIETY RESULTS: CONTROL GROUP .............................. 62
4 MATH ANXIETY RESULTS: JOURNAL WRITING CLASS ................ 63
5 MATH ANXIETY RESULTS: OPEN-ENDED QUESTIONS CLASS .......... 64
6 OPEN-ENDED QUESTIONS RESULTS: CONTROL GROUP .............. 66
7 OPEN-ENDED QUESTIONS RESULTS: JOURNAL WRITING CLASS ...... 67
8 OPEN-ENDED QUESTIONS RESULTS: OPEN-ENDED CLASS ............ 68
9 FINAL EXAM SCORES .......................................................... 70
CHAPTER 1
WRITING IN MATHEMATICS

Change is continuous in our society. As the use of technology increases, so do the skills of our work force. Individuals need to be capable of organizing data, explaining complex processes to others, as well as making conjectures about different topics. Individuals must be able to learn these skills in order to be successful. The educational system is the foundation for teaching these new skills. As society changes, so must teaching strategies. One rationale for change states:

As society shifts from an industrial age, in which a person could get by with basic reading and arithmetic skills, to an information age, which requires the ability to access, interpret, analyze, and use information for making decisions, the skills and competencies needed to succeed in today's workplace are changing as well.

(Baker, 1991, p. 1)

In response to this change, educators must alter the way that they teach mathematics. The lessons need to focus more on problem solving and communication in the classroom. Students need to be taught to be critical thinkers.

Steele and Arth (1998) state that "Teachers have a responsibility to help students learn content, but also to prepare them for their roles as critical thinkers in today's information age" (p. 1). They urge educators to stop teaching students to memorize equations and perform meaningless tasks, but rather to teach skills of problem solving. The Illinois State Board of Education in Learning Standards (1997) also emphasizes this point in its mathematics goals. The document states, "[Students] will be able to read, write, visualize, and talk about ways in which mathematical problems can be solved in both theoretical and practical situations" (p. 16). The Standards also state that
mathematics education is more than computation and memorization. They challenge teachers to emphasize investigating, reasoning, visualizing, and communicating mathematics in a meaningful way. These state standards reinforce the idea that education should be practical and meaningful in a student’s life.

Another advocate of educational change is the National Council of Teacher of Mathematics (NCTM). This influential organization also stresses the importance of communication in mathematics. The NCTM (1989) has five major goals for students:

1. learn to value mathematics
2. become confident in their ability to do mathematics
3. become mathematical problem solvers
4. learn to communicate mathematically
5. learn to reason mathematically.

“The development of a student’s power to use mathematics involves learning the signs, symbols, and terms of mathematics. This is best accomplished in problem situations in which students have an opportunity to read, write, and discuss ideas in which the use of language of mathematics becomes natural. As students communicate their ideas, they learn to clarify, refine, and consolidate their thinking” (p. 2). The NCTM stresses that students learn by communicating their ideas to others. This process aids them in their problem solving ability.

Educators are always looking for ways to improve their teaching methods to keep up with the latest benchmarks and goals that are presented. One major need to be addressed is the lack of student communication, especially writing, in the mathematics classrooms. Students need to be given the opportunity to express ideas, argue points of interest, and explain the solution process. Many educators and organizations support this
method of instruction. The benefits of writing on a regular basis, far outweigh any negatives.

The NCTM (1989) states, “Writing is a communication skill that has been used too infrequently in mathematics” (p. 28). It goes on to argue that children learn through verbal communication, and this learning method should continue through writing. Students require communication to learn new things. They must be able to explain what they know as well as how they know it.

Joan Countryman (1992) states that “To learn mathematics, students must construct it for themselves. They can only do that by exploring, justifying, representing, discussing, describing, investigating, predicting, in short by being active in the world. Writing is an ideal activity for such processes” (p. 2). The process of writing allows students the opportunity to perform all of the mentioned activities. William Zinnser (1988) emphasizes this point. He states, “Writing is a way to work yourself into a subject and make it your own.” He believes that once someone writes about a topic, that individual has become an active learner.

Although many educational organizations and educators advocate the use of writing in mathematics class, there are still those who oppose this implementation. These teachers would argue that their curriculum is already full without writing. They may argue that they are paid to teach mathematics, not English skills. Other teachers will argue that the time commitment outside of class is too substantial (Reid, 1998). Still, others will say that they learned math just fine by rote memorization and drill and practice (White & Dunn, 1989). These teachers believe that all students learn the same way. While all of these are valid concerns, the following information will offer evidence that will show that writing in math class is a beneficial method of instruction. The
purpose, benefits, types, assessment, as well as implementation of writing in mathematics class are all discussed. It will become clear that the benefits of this process far outweigh any negatives.
CHAPTER 2
MATH ANXIETY

Teaching math is a very unique experience. Mathematics is perhaps the only discipline in which students will admit that they are “not good at it”. Children have grown up with the notion that mathematics is a talent that is not learned, but inherited. This belief makes mathematics a difficult subject to teach. Fear of mathematics is often referred to as math anxiety. Fiore (1999) describes math anxiety as “The panic, helplessness, paralysis, and mental disorganization that arises among some people when they are required to solve a mathematical problem” (p. 403). This anxiety can stem from many sources and is a major obstacle to overcome when teaching mathematics.

Causes of Math Anxiety

One of the main sources of math anxiety is the method of teaching that most educators use. When teachers explain, practice, and then force students to memorize facts with no explanation, students are discouraged (Steele and Arth, 1998). Children are creative and inquisitive by nature. They want to know what they are doing and why this method is used. Steele and Arth state, “When we teach math without meaning, we force students to memorize unconnected bits of information. As a result, math doesn’t make sense to them” (p. 2). This trend leads to math anxiety.

Another cause of math anxiety is what some call sudden death in mathematics class. Students do well in class until they find that a certain topic is suddenly very difficult. Instead of asking for help, students fear that asking questions will make them seem less intelligent. Students, therefore, hit a proverbial wall. They get the feeling that it is no longer possible for them to be successful in mathematics (Tobias, 1978). Now,
although the student may have the ability to do math, it is hidden by math anxiety (Fiore, 1999).

Emphasis on the right answer is another cause for math anxiety (Tobias, 1978). A problem in mathematics is often presented in such a way that implies that there is only one solution. Many students enjoy solving problems in a unique way. Not all students think the same way. This restriction on independence causes many students to turn away from mathematics.

**Solutions**

Educators need to address the issue of math anxiety for class to be successful for all students. This can be done only if teachers open the lines of communication with their students. Teachers need to determine how their students value mathematics and how they learn. Writing in class can start this communication process. By asking students to write about concerns and problems, teachers can address why these students have not been successful. This can enable teachers to end this trend of math anxiety.

In addition, change needs to occur in the mathematics classroom. Fiore (1999) states, “Preventing and overcoming math anxiety begins with teachers and teaching strategies that develop positive and realistic self-concepts” (p. 405). Educators need to make students feel that they are in a supportive learning environment. Steele and Arth (1998) state, “Helping students learn to reason and verbalize their mathematics thinking convinces them their thinking is important. When thinking is rewarded, it will continue” (p. 2). By striving to make all students feel valuable, teachers will give confidence to students who had previously lacked it. An environment with communication is much less stressful.
Lastly, teachers need to emphasize to students that multiple strategies are encouraged. If students can write an explanation that supports their method, they should receive credit for their work. Some supporters of writing in the mathematics classroom believe that by thinking, proving, evaluating, and explaining, all students can be very successful. Teachers should support creativity through written explanations.

While math anxiety is a major problem in schools today, it can be overcome with the proper teaching techniques. Although writing will not correct every problem, it will open the communication between teacher and students. This may encourage some students to overcome their math fears. Writing in class will also enable teachers to see what misconceptions their students have about learning mathematics. While these are a few of the purposes of writing in mathematics class, many more exist.
CHAPTER 3

PURPOSE OF WRITING IN MATHEMATICS

Although using writing in mathematics class has been known to assist in easing math anxiety, writing in mathematics has many other purposes as well. Each educator must have a specific reason for implementing a writing program. Teachers need to know their strengths and weaknesses as educators and try to implement programs that will work to improve their teaching.

Open Lines of Communication

Probably the most important purpose of writing in mathematics is to begin communication with students. Teachers can learn many things from reading what students have to write. When asked to put thoughts down on paper, students will open up and communicate very well. Teachers can provide many different prompts to elicit their desired information. Educators can ask students about past learning experiences, likes and dislikes, mathematical knowledge, or general opinions. Writing in class can also provide teachers with insights into how a student may learn or think (Burns, 1995). If a teacher knows how a student learns most effectively, that teacher can adapt his teaching style to suit that individual. Both the teacher and student can benefit from this type of dialogue (Reid, 1998). Marwine (1989) writes, "I would maintain that having students engage in various forms of informal, ungraded writing exercises is a valuable addition not only to check on the quality of the communication but also to provide ways of immediately enhancing that quality for both teacher and student" (p. 59). This type of communication can greatly affect the learning environment in any mathematics class. Communication is not only limited to the classroom. Teachers can save student writing for discussions with parents (Burns, 1995). This enables teachers to share student
progress with parents. Therefore, writing in mathematics class opens communication for students, teachers, and parents.

**Student Assessment**

In addition to communication, writing in mathematics class can be used as a form of student assessment. When there is a class discussion, only one student can answer at a time. When asked to perform a writing assignment, every student has the opportunity to participate (Burns, 1995). The teacher is given the opportunity to assess many students at the same time. Countryman (1992) writes:

> Although the most common form of evaluations is testing to assign grades, assessment is more than just the administration of quizzes and tests; it is continuous and dynamic, and its purpose is to promote learning. Writing in mathematics can be a significant part of this effort. (p. 76)

Writing allows teachers to learn much more about students than conventional exams.

Students can also use writing as a learning tool. Students can write explanations to different prompts and then later reflect on their responses (Burns, 1995). This provides a concrete way for them to review any work that they have done. Writing in mathematics also allows for students to see that mathematics is more than just number crunching (Countryman, 1992). They can experience the process of mathematics rather than just simply complete an algorithm.

**Interdisciplinary Units**

Finally, writing in mathematics class is a method for combining subjects. Writing across the curriculum is a trend that is becoming very common in schools today. For example, students can solve mathematical problems about science topics and then write an explanation to describe this process. By combining science, mathematics, and writing
teachers can enhance the learning process for all students. They can show the relationships among disciplines and demonstrate this to their students. All of these are purposes for writing in mathematics.
CHAPTER 4
BENEFITS OF WRITING

The purpose of writing in mathematics class explains why teachers start a writing program. On the other hand, the benefits describe the positives that result from such an endeavor. When writing is done on a regular basis, everyone benefits. The students find it very rewarding, teachers are assisted, and the classroom environment is much more conducive to learning.

Student Benefits

One group that benefits greatly from the use of writing is the students. Primarily, writing is an opportunity for students to reflect. They can think about mathematical ideas, processes, and relationships, as well as their personal knowledge. When students are asked to write about a specific topic, they become aware of what they know or do not know (Countryman, 1992). Students may be able to solve a problem using an algorithm, but do not know why they are performing this task. Having students write about this process, forces them to evaluate their knowledge. Bosse (1995) explains, “The writing process itself provides opportunities for self-assessment” (p. xii). When students have an understanding of what they need assistance with, they can then ask for help. Students can then have more control over their learning.

Writing about mathematics is also a learning process for the student. Cranell (1994) writes “By explaining a difficult concept to other people, you end up explaining it to yourself” (p. 1). Writing forces you to organize your thoughts so that you can provide a complete explanation to the given question. Connolly (1989) states, “‘Writing to learn’...is about writing that is done regularly in and out of class to help students acquire a personal ownership of ideas conveyed in lecture and textbooks” (p. 3). This writing...
allows students not only to relay their thoughts to others, but also to learn during this process. Pugalee (1997) believes that writing actually builds thinking skills. He believes that this process forces students to synthesize their thoughts. This forces them to think critically about mathematics. This method of learning is very beneficial to students in any mathematics classroom.

In addition, writing gives students a written record of their thoughts. Students can later review or revise their thinking about specific topics. Legere (1991) writes, “Writing requires an involvement, a shaping of thought, a commitment. It produces a product that allows the writer to review, revise, and shape anew” (p. 170). Students may answer a question in class or have an idea in their head, but until it is written, the thought may be lost. Students need to have the ability to revise their thinking. Writing thoughts down on paper, gives them a record of thinking. Countryman (1992) states:

I have noticed that informal writing encourages students to struggle with new material, to let themselves wonder, speculate, and experiment with ideas. Writing down these speculations makes a record of them, and allows students to look back on something of their own making. (p. 88)

Students often learn about one topic after another. Once they are tested over one chapter, they tend to forget this material and move on to the next. Having a written record allows students to revisit their thoughts and ideas at a later time.

Writing also allows students to feel more comfortable in math class. While taking tests and doing problem sets is very frustrating for some students, writing in mathematics class is a more non-threatening type of classroom work (Carter & Carter, 1994). Some students feel that writing provides them with some freedom. They are not afraid to make mistakes when they are doing informal writing in class. This freedom also benefits
students who have some form of math anxiety. Connolly (1989) states that writing in mathematics can help students “overcome the anxiety that occurs when education stresses answers, not options, and product, not process” (p. 6). The author believes that writing gives students a vehicle to learn in a less stressful environment.

Overall, writing in mathematics class can benefit students in many ways. They can feel more at ease in a class that is stressful at times. Students can concentrate on learning to do mathematics rather than memorizing facts and algorithms. They can communicate their learning to others as well as reflect on their own thoughts. Writing assists all students in the mathematics classroom.

**Teacher Benefits**

Teachers also benefit greatly from having students write in class. Educators can open lines of communication, assess student knowledge, reflect on teaching techniques, vary teaching style, and improve assessment procedures. Teachers have the ability to improve the learning environment by implementing a writing program in their mathematics classroom.

Primarily, writing will open the lines of communication in any mathematics classroom. Pugalee (1997) believes that writing can be used as a “powerful diagnostic tool for the classroom teacher” (p. 2). By having students write to answer specific prompts, teachers can assess student knowledge. Writing is an excellent opportunity for teachers to receive feedback from students about mathematical topics (Countryman, 1992). By having each student write a response, the teacher can receive information from every student, not just the one raising his or her hand in class. Every student is accounted for during a lesson. Writing not only is a tool to assess lack of knowledge, but it is also a means to interpret misconceptions. Carter and Carter (1994) write:
When writing their responses, students are forced to rely on words to illustrate their understanding rather than a string of symbols that may mean nothing to them... Assessment of students' knowledge is more complete because one can pinpoint errors in the students' conceptual development. (p. 4)

Students are able to relay this information more freely when writing is used for assessment. "Writing furnishes a more in-depth picture of the mental process of students as they work on mathematics" (Pugalee, 1997, p. 2). Reading student responses can enable an educator to find topics that are confusing to the class. Teachers can address these problems in the next class session and correct any student misconceptions.

Teachers also benefit as educators. By having students write in class, teachers can get a fresh attitude about teaching (LeGere, 1991). Many educators teach the same way year after year. Writing offers a means to change the environment of the mathematics classroom. Teachers may benefit from this change from the norm. Educators can offer prompts that allow for teacher self-evaluation (Dougherty, 1996). If most students write about not understanding a particular topic, the teacher can critique the lesson that was used to present this material. Maybe the students are having difficulty because the material was not presented in an effective manner. Burns (1995) writes, "Reading students' papers helps teachers evaluate how well the instructional program is supporting learning goals" (p. 29). She believes that this is a form of in-class assessment. This method would serve some of the same purposes of district and state assessment tests. The responses would provide the teacher with information about what is being taught well and what needs improvement. Many teachers would argue that their schedules are already full without writing in math class. One educator believes, "The time spent in helping students explain clearly what they mean will lead to major savings
in instruction time later on” (Reid, 1998). By finding difficulties early in the learning process, teachers can benefit by correcting mistakes early. This will save time in the long run of the school year. Teachers greatly benefit from having students write in their mathematics classes. The time spent reading these entries will improve the learning environment for both teachers and students.

**Classroom Benefits**

Writing in mathematics also benefits the classroom environment as a whole. Writing allows for interdisciplinary units, higher classroom expectations, equal contribution among students, as well as an improvement in classroom learning. Many involved in the learning process will benefit from writing.

Primarily, writing in mathematics can be used to connect mathematics with other disciplines. This process allows for topics that are usually discussed in English, science, or social studies to be analyzed mathematically (Shafer, 1992). Teachers can work cooperatively to introduce a topic in science, solve problems in mathematics, and then write results about the information gathered. Students can benefit greatly from making this connection. Carter and Carter (1994) state, “Writing about mathematics helps students see new connections between the various subjects they are studying” (p. 4). When students see that mathematics can be related to other disciplines, they value the information more. Therefore, writing can benefit students by doing interdisciplinary units.

Another benefit of writing in the mathematics classroom is emphasis on higher classroom expectations. When writing is used effectively, answers are not the most valuable part of a student’s work. Legere (1991) believes that writing promotes processing and interpreting information rather than simply relying on correct or incorrect
answers. Teachers and students can focus on the process of solving problems rather than simple rote memorization. This "promotes good rapport and a positive classroom environment" (Miller, 1992, p. 355). Everyone involved benefits from the increased focus on solving problems and learning mathematics. The class also benefits because everyone is involved. By writing in the classroom, every student is active. When teachers ask for verbal responses, only one student can answer a question at a time. With writing, every student is actively working at the same time (Countryman, 1992). This also benefits the class as a whole.

Writing in mathematics also improves the atmosphere of most classrooms. Writing allows students to share ideas with other students (Ryan & Rilerro, 1996). When student responses are read aloud, it gives every student an opportunity to hear alternate methods or ideas. Students can learn that they are not alone when it comes to solving mathematical problems. They are given the opportunity to discuss their similarities and differences in learning mathematics. This communication also allows students to raise questions about new ideas (Countryman, 1992). Students who have questions can benefit from the open forum of discussion that can be accomplished. By using writing as a means of communication, students can share questions and answers that may not have been asked in the average classroom. Students and teachers benefit greatly in this type of learning environment.

Writing in mathematics class benefits students, teachers, and the classroom environment when adopted as a regular teaching tool. Teachers can adopt various types of writing to accomplish specific goals. These educators will need to decide which type of writing prompt will benefit their classroom the most. The most common types of writing prompts that can be used in mathematics are discussed in the next section.
CHAPTER 5

MATHEMATICS JOURNALS

Journals are probably the most used type of writing in mathematics classrooms. Journals are an excellent teaching tool for educators to implement in their classrooms. Teachers have students write a response to a given prompt either during class or as homework. Students respond to the prompt and eventually hand in their writing to the teacher for evaluation. Teachers then respond to the students’ entries. This is an ongoing process of communication throughout the school year. Countryman (1992) writes:

I tell them [students] that a journal is a chart of their journey through the course and a way for them to keep track of where they are going, and where they have been, as they struggle with the stuff of mathematics.” (p. 27)

Journals offer both the teacher and the student a written record of communication of learning for the entire year.

Purpose of Journals

Writing in journals has three purposes. Primarily, students can express opinions and beliefs. Journal entries allow students to express their ideas to teachers in a private manner. They do not have to raise their hand in class and offer an opinion to the entire class. Rather, they are allowed to be completely honest by knowing that their responses will remain confidential. Carter and Carter (1994) write, “Journal writing is meant to be a non-threatening writing opportunity in which students are able to express their opinions, possibly about controversial issues, and evaluate their progress in class” (p. 13). This process allows students to feel free to express things that are normally kept silent.

Journals can also be used as an instructional tool. Teachers can give prompts that force the student to think critically and answer mathematical questions. Norwood and
Carter (1994) believe that journals can be used in three different ways to improve learning. They believe that certain entries can assess knowledge prior to discussion, assess topics that are being discussed, evaluate how students are learning at any time during a lesson, or focus on the review of a topic. Tobias (1978) feels that journals help "show the student and the instructor the recurring mathematical errors that are getting in the way and to make the student hear his own 'self-talk'" (p. 67). Teachers can use journal entries to evaluate student work and then respond to correct the errors. Again, this enables educators to find many student misconceptions that would remain hidden during a regular mathematics class.

Journals are also used to increase communication in the classroom. Teachers usually do not interact with every student on a regular basis because of time restraints. Journals allow for written conversations to occur between the teacher and every student in the class (Rose, 1989). Educators give students a prompt to write about. When students turn in their responses, teachers can respond to what the students have written. Students can then read what the teachers have written back to them. This begins a communication process that will make the learning environment much more effective. Therefore, the purpose of mathematics journals is to start communication, evaluate student knowledge, and serve as a means of expression.

**Implementation of Journal Writing**

Although some of the basics of journal writing have been discussed, many more ideas exist about the implementation of mathematics journals. Primarily, where do students write their journal entries? Many educators believe that students should buy or be given a separate notebook to keep as a journal (Rose, 1989). Others believe that individual sheets of papers will be acceptable. Teachers usually organize these entries in
individual folders after reading them. Both of these choices require journal entries to be separate from any other assignments and kept in the classroom. This gives students the opportunity to have a record of their entries that are in a chronological order. A student and the teacher are the only two individuals who can view this information. Many other teachers require students to keep their entries in their mathematics notebooks (Carter and Carter, 1994). Students are asked to keep journal entries in the same notebook with class notes, homework, and other assignments. This allows students to keep entries with similar information all in one place. Either way, students can always read and reflect on their entries.

After teachers decide where they want students to write, they must decide when they are going to have students write. Some educators believe entries should be part of a homework assignment. Williams and Wynne (2000) believe that prompts should be given toward the end of the class. Students should begin their responses in class and then finish them at home. This allows all students to have a chance to complete their entries. Many other teachers prefer to have all writing done in the classroom. This ensures that entries will not be forgotten or lost before turning them in to the teacher. By having students perform writing in class, teachers can monitor student work. This also assures that everyone will write an entry to the given prompt (Carter and Carter, 1994). Therefore, every student will be active during the class period.

If teachers assign in-class writing, they need to decide which part of class time to use. Three different times are suggested (Reid, 1998). Journal writing can be done at the beginning of class. This allows teachers time to take care of administrative duties like attendance during the first five to ten minutes of class. This also offers time for students to write about prompts that focus on review of covered material. Teachers can begin the
period by having students write about material that was discussed the previous day. This allows for continuity throughout the teaching unit. Teacher can also choose to have students write in their journals in the middle of class. Educators can discuss a topic or problem and then assign a writing prompt. This method of instruction can be used to refocus students on the discussion or to evaluate them on the new material. Either way, teachers can direct students to focus on the topic being discussed. Lastly, teachers can have students write at the end of the class period. This time can be used to summarize what was covered in the day’s lesson. Teachers can read these entries to see if students understood the material that was discussed that day. This is also an excellent teaching tool to use in the often neglected last five minutes of the period. In summary, teachers can choose any part of class time to assign writing prompts. Teachers must decide which method best suits their instructional goals.

Teachers also need to decide what types of prompts to give students. Educators can ask a variety of questions that deal with mathematics. On the other hand, teachers can have students just write about any topic, mathematical or not. Students will find that this freedom is a time for them to state what they value as an individual. Although this can be very beneficial, teachers will want to concentrate on mathematics most of the time. Three types of mathematical prompts are available for teachers to use (Reid, 1998). First, teachers can assign mathematical prompts. These will be entries that explain the process of solving a problem. Teachers can ask how a certain problem would be solved or what is the best method to be used on a particular problem. Students provide entries that allow teachers to evaluate student knowledge. Dougherty (1996) believes:

Using the idea that students develop their mathematical understanding over time, the content prompts should follow the introduction of a new concept by three or
four days. This interval gives students time to explore a concept before moving to
a high level of thinking. (pp. 557-558)

By allowing students to work with a topic for several days, teachers can evaluate their
knowledge after they have been given time to explore their knowledge. This type of
prompt is an excellent assessment tool for instructors.

The second type of journal entry is a process prompt. Dougherty (1996)
describes, “Process prompts offer opportunities for students to reflect on why they choose
or prefer particular solution strategies and to consider ways in which they learn” (p. 558).
This type of prompt allows students to be critical thinkers. They need to justify why they
prefer specific strategies when solving problems. Students are forced to become more
aware of how they think. Other process prompts can focus on how students review
material or study for exams. Teachers can gain excellent information about how students
approach many aspects of learning mathematics. Lastly, process prompts display
diversity in the classroom. Students can recognize that different students learn in various
ways. Students can become comfortable thinking for themselves as mathematicians.

The third type of journal prompts is affective/attitudinal prompts. These enable
students to answer questions about how they view themselves as learners and problem
solvers. Teachers can ask students to give their opinions on different topics. Educators
may discover why students succeed or fail based on their preconceptions about learning
mathematics. Teachers can find and interpret patterns that exist in attitudes toward
learning. By using this information, teachers can discuss these trends with students or
parents. This may allow more students to become successful in mathematics. Attitudinal
prompts allow the teacher to gain a holistic view of every student in class. By using all
three types of mathematics prompts, teachers can gain valuable information about every student.

**Benefits of Using Journals**

The use of journals in mathematics class has a multitude of benefits for students and teachers. Journals are a means of assessment. Also, writing in journals provides a method of learning for students. Journals also help create connections with mathematics and other disciplines as well as open the lines of communication between students and teachers. Lastly, journals are a means of self-assessment for teachers. The following is an explanation of each benefit.

**Assessment**

Journals are an excellent means of alternative assessment. Teachers usually give short answer mathematics questions to students. These students write down answers for teachers to grade. While checking these answers, educators only learn whether or not students answer correctly. Journals, on the other hand, allow teachers to obtain an understanding of what students really do or do not understand. Countryman (1992) writes, “Reading math journal entries tells me considerably more about what students grasp and do not understand, like and dislike, care about and reject as they study mathematics than any formal or traditional assignments” (p. 28). These entries not only allow teachers to evaluate student knowledge, but also enable teachers to determine how students learn. By reading a class set of responses, the teacher can diagnose many student misconceptions (Chapman, 1996). If many students have similar incorrect responses or ideas, teachers can correct these common mistakes toward the beginning of a specific unit rather than wait until a unit or chapter exam.
Teachers and students are not the only people who benefit from journals. Parents can also benefit from student written journals (Stix, 1994). Teachers or students can share journal entries with parents. This enables parents to assess their children's learning. By reading journal entries, parents have a written example of the student work to discuss with their child.

Overall, for educational improvement to occur, teachers need to understand student thinking (Norwood & Carter, 1994). Journals are excellent tools for this type of assessment. By finding out what students know and do not know, teachers can improve the learning in their classrooms.

**Learning through Journals**

Journals also benefit student learning. By writing responses to specific prompts, students are forced to think critically about mathematics. Writing forces students to slow their thinking process (Rose, 1989). By slowing down this process, students are required to organize their thoughts and answer questions with more detail. This enables students to have a "better understanding and retention of math" (Stix, 1994, p. 264). Students remember topics much more when they construct their own written explanation. Journals "provide a way for students to review or interpret information discussed in class or read in a text" (Manning & Manning, 1996, p. 2). The benefit of using a journal is that it is a tool to "enable students to use the skills of reading, listening, viewing, and questioning to interpret and evaluate mathematical ideas" (Norwood & Carter, 1994, p. 148). By writing what they know and do not know, students learn by organizing their mathematical knowledge in writing.
Making Connections

Another benefit of student journals is that they help provide a means to connect mathematics with other subjects. Journals allow students to construct a bridge between concrete modes of thinking and abstract modes of thinking (Stix, 1994). Students can use writing to link their verbal and visual knowledge with personal experiences. Students can use abstract mathematical knowledge and connect this to other subjects like English, science, or social studies. Carter and Carter (1994) explain:

Students might be asked to explain what forms of mathematics are used in any other class they are taking. After students have written this journal entry, the teacher might ask them to share their responses with the rest of the class, thereby broadening other students’ perspectives on applications of mathematics.” (p. 14)

Therefore, writing allows for students to connect mathematics with many other subjects.

Communication

Increased communication is another benefit of journals. Journal entries allow students to express attitudes and feelings about mathematics (Steele & Arth, 1998). Teachers can read these entries and respond to them. This starts a line of communication that continues throughout the school year. This communication allows students and teacher to become acquainted with one another. Journal dialogues allow student to express opinions that they may normally keep to themselves. Journals provide a very non-threatening means of communication for students (Carter & Carter, 1994). Students who would normally sit and never say anything in class are given the opportunity to write their feelings in a journal that only a teacher will read. This allows teachers and students to obtain a better rapport in the classroom. Lastly, journals allow for communication to occur more frequently. While regular question and answer sessions only allow one
student an opportunity to speak at a time, journals allow every student the chance to respond at once. The teacher receives communication from everyone at the same time. Therefore, journals allow communication to occur more frequently.

**Self-Assessment**

The final benefit of journals is the ability for teachers to self-assess themselves as educators. Teachers can read student entries and evaluate their teaching strategies. "If students are comfortable with the journal writing process, they will offer information that the teacher could use to improve the instruction of the class" (Reid, 1998). Students are always eager to volunteer their opinion about how things could be improved. Teachers can use this feedback to improve their teaching techniques. Journals allow both teachers and students to benefit from writing in mathematics class.

**Teaching Tips for Journals**

Now that the benefits of using journals have been given, it is time to discuss how to implement this process in the classroom. Journals can be an overwhelming task. The following is a summary of tips those educators who use journal-writing feel to be effective.

When teachers begin changing and adapting their teaching strategies, they sometimes find it difficult to get started. With journals, it is best to start at the beginning of the school year (Norwood & Carter, 1994). Children also find change difficult. By starting at the first of the year, both teachers and students are adapting to one another. The transition from non-writing to writing is just one of many. Students may find this new technique very beneficial when getting to know the teacher. Writing from the start also provides the students with expectations for the entire year. It is best to let them know that writing will be an integral part of the curriculum.
Teachers need to decide how they would like the journal writing process organized. The most popular method is to have students write in a separate notebook (Bosse, 1995). This spiral notebook is used solely for journal writing. Teachers can purchase enough notebooks for the students or have them purchase their own. When students have notebooks, they can draw on the cover or decorate them to their liking. It is recommended that these notebooks stay in the classroom. This serves many purposes. First, the journals remain private, away from other students. Second, teachers always have access to these journals. This makes it very easy for teachers to respond or grade entries. Also, students cannot lose journals that remain in the classroom (Reid, 1998). Once teachers decide their organizational method, they are ready to begin introducing this new concept to their students.

Teachers need to explain what is expected of each student in their journals. Primarily, students need to be told why they are being asked to write. By explaining the benefits of journals to the class, teachers inform students as to what is expected of them (Countryman, 1992). Students are curious and will always question change. Therefore, teachers should be up front with their students and answer any questions in advance of writing. Teachers should stress that they are the audience for journal entries (Reid, 1998). Students need to understand that they are having a one on one conversation with the teacher through writing. This gives the student a focus when he begins writing.

Next, teachers need to explain what is to be written in the journals. Journals can include explanations, diagrams, tables, lists, flow-charts, or any other means that will express the desired ideas. Students need to understand that anything can be used in a journal. It is a vehicle for communication. Anything can be included and creativity should be promoted.
Students usually need to be given examples to understand a new concept. Journals are not different. Teachers need to provide quality writing for students to model (Norwood & Carter, 1994). This is particularly important at the beginning of the writing process. Teachers should make up a journal prompt and write their own entry to share with the class. This gives students a better idea of what is expected of them. Teachers can model the organization, length, and structure that they expect their students to follow. Then, once students become comfortable writing in their journals, they can become more independent and creative with their writing.

After students have written in their journals, teachers need to respond. McIntosh (1991) writes, “Teacher response is vital to the success of journal writing” (p. 430). The process of responding completes the communication process. For journal writing to be an effective tool, students need to know that the teacher values their entries. By responding to the entries, teachers support and promote student work.

Responses can be done several ways. The most important thing is that they are done frequently (Norwood & Carter, 1994). Most experts say that teachers should respond at least once a week. This ensures that students receive constant feedback. This process also guarantees that teachers will not have to read more than five entries from one student at a time. This requires teachers to stay caught up with student work and not get bogged down with paperwork later. Most teachers respond by writing. They write their responses on the same page as the student entry. Therefore, students can reread their entries and then read the teacher response. When writing responses, teachers should be sincere and not judgmental (Reid, 1998). Teachers should encourage openness in student journals. If students are criticized, they will be more reluctant to write about their feelings later. One method of response is by using post-it notes. Teachers can respond
on post-it notes and stick them on the pages of student journals (New Jersey Mathematics Coalition, 1996). Students can read the responses and choose to leave them or discard them from their journal. This allows students to keep a notebook with only their work written in it.

Another method of response to journal entries is verbal response. Educators can discuss a student entry in person (Reid, 1998). Although not frequently used, some student writing may need to be addressed through conversation. A teacher can have a conference with a student after class or at the beginning or end of a teaching period. Either way, communication is the key to journal writing success.

Grading vs. Not Grading

Probably the biggest question about mathematics journals is whether or not to grade student entries. Some educators believe that if an assignment is not graded, it will not be taken seriously (Reid, 1998). While this may be true, grading can take many forms. If assigning grades is a priority, teachers can give completion grades rather than content grades. Mathematics teachers do not need the added responsibility of correcting grammar and other English skills. Chapman (1996) states, “More students become actively engaged in the spirit of the journal as a medium for communication” (p. 589). By not being graded on content, students can write more freely (New Jersey Mathematics Coalition, 1996). Students need not worry if their opinion is not completely correct. Journals should provide a non-threatening means of mathematical communication (Reid, 1998). Grading on content undermines the very purpose of the activity. Therefore, teachers should read entries, respond to the student, and then assign a completion grade if necessary. This effectively enforces the use of mathematics journals.
CHAPTER 6
OTHER TYPES OF INFORMAL WRITING

While journals are probably the most frequently used type of informal writing, many other forms also exist. Teachers can use autobiographies, learning logs, or freewriting to learn more about students. Educators can implement the use of letters, posters, skits or plays, displays, or other types of creative writing in the classroom. The following is a description of several types of informal writing that teachers use in their mathematics classrooms. These descriptions are not nearly as in depth as that of the journals, but enough information is given to explain the idea of the concept.

Mathematical Autobiographies

Mathematical autobiographies are personal accounts of how students have learned mathematics. Students have the opportunity to describe their mathematics history to their teacher. Autobiographies are usually assigned at the beginning of the school year. This method of writing is an excellent opportunity for teachers to start the writing process in mathematics. If teachers are using journals, this can be the first entry of student journals. Students find out that writing is valued at the beginning of the school year. Autobiographies also allow teachers to get to know their students. Fiore (1999) explains, “It [autobiographies] allowed students to tell their instructor about themselves, to put on paper in the privacy and comfort of their homes what they might not be able to verbalize in school” (p. 404). Teachers can gain an understanding of mathematical attitudes before the semester even begins (LeGere, 1991).

Many different ideas can be discussed in an autobiography. Students can describe how their families value mathematics. Steele and Arth (1998) write, “They [students] explain their personal math backgrounds beginning with experience in the family” (p. 3).
Students can explain their parents’ opinions of mathematics and any other experiences they have with their parents or siblings. Students can describe whether or not they receive assistance at home or are responsible for their own learning. Students can also describe their personal learning styles. They can describe their strengths or weaknesses in mathematics class. Students can also explain what aspect of mathematics they enjoy or dislike (Rose, 1989). Autobiographies give students the opportunity to explain how they learn to their teachers. In turn, teachers already have an understanding of how they may need to teach to be effective for some students. Autobiographies are an excellent way to begin the school year.

**Learning Logs**

Learning logs are very similar to student journals. Unlike journals, learning logs mostly deal with mathematical content. Rose (1989) describes learning logs as a “notebook for recording examples of classroom discussions” or a “personal record of what transpires in class” (p. 15). Learning logs allow students to write about class examples and describe how to solve problems. A learning log is a summary of how that individual student learned certain concepts.

Learning logs are beneficial to both students and teachers. These entries are very beneficial when students want to look back and review past lessons. Students can write about how to do something, put definitions in their own words, or write specific examples of problems they have solved. All of these entries allow students to record their learning. Learning logs are also beneficial to teachers. Teachers can read student entries and discover misconceptions that may occur. “When teachers read students’ definitions, misconceptions that may otherwise go unnoticed become apparent, thereby helping teachers identify areas that need re-teaching” (McIntosh, 1991, p. 424). By having
students keep a learning log, teachers gain an assessment tool. Teachers can discover many problems that students would otherwise keep to themselves. Learning logs provide a means of communication between teachers and their students.

**Free-Writing**

Another means of informal writing is free-writing. Teachers can assign this type of writing when there are a few free minutes left at the end of class. When free-writing, students write anything that comes to their mind in a short period of time (Countryman, 1992). Students are given a topic and write any idea that comes to them. Connolly describes free-writing as thinking aloud on paper. This process allows students to communicate their ideas and beliefs to teachers. Responses are short and can be as creative as desired. This is a very quick and easy method for students to write in mathematics class. Teachers also benefit greatly because of the information that is received from every student.

**Posters and Displays**

Students can also be asked to make posters or other types of displays for mathematics class. Teachers can pick topics and have students create visual aids that explain and describe the required information. Students are encouraged to be creative and artistic when presenting their information. By having students create posters, teachers allow students who may be creative or artistic an opportunity to excel in mathematics. These displays also give every student a visual explanation of a mathematical topic or problem.
Letters

Letters also provide an excellent means for writing in mathematics class. Students can be asked to write letters to other students, family members, or even the teacher. These letters can describe mathematical processes. Students can write a letter to a student at another school and describe what they are studying and how they are solving certain problems (Manning & Manning, 1996). This allows students to put their thought processes down on paper in a familiar setting. All students have written a letter before, so this should be a comfortable writing medium (Rose, 1989). Students perform much better in a non-threatening environment. Letter writing provides that atmosphere in the classroom. Letter writing can also be done via the internet. Students can use email to communicate with others by writing letters (Manning & Manning, 1996). Whichever method of writing letters is used, students will benefit by writing mathematical ideas.

Creative Writing

Creative writing is also a method of writing in mathematics class. Educators can ask students to produce poems, stories, skits, or plays about mathematics. Teachers can assign problems that force students use critical thinking skills to discover creative answers to these assignments. Burns (1995) writes, “An assignment that calls for a fanciful approach can give students a fresh way to think about mathematical ideas” (p. 103). These assignments allow for students to individualize their work. Students enjoy being different. By assigning work that requires creative answers, students are allowed to be individuals. When describing an assignment in her trigonometry class, Barnes (1999) stated:

My goal was not only to alleviate their fears by assigning interesting problems but also to place students in a setting in which they had to use critical-thinking skills,
express their ideas verbally with other students, express their mathematics in writing, and have fun. (p. 498)

Too much of mathematics is boring and stagnant. By giving writing assignments that require creative answers, teachers can improve the learning environment in their classrooms. Students can learn mathematics while enjoying the activities.

Creative writing assignments can be as unique as the teacher or student who creates them. Kane (1999) requires her geometry students to write a book of creative geometry. Students must write a book that uses geometric concepts in a storybook method. Prompts for this assignment include a geometric poem, comic strip, cartoons, nursery rhymes, or geometric greeting cards. Each student is responsible for a part of the book. This process requires students to use concepts learned in class to entertain others. Each student is responsible in completing the class book. Kane (1999) believes that this process “allows students to sort out ideas, reinforce their understanding of concepts, or discover weaknesses in their understanding of concepts” (p. 800). Creative writing in mathematics class is an excellent form of alternate assessment. Teachers can evaluate student learning while creating an enjoyable learning environment for learning.

**Summary**

Teachers who do not use writing in mathematics class can greatly benefit from using one of the discussed informal writing prompts. Teachers can learn so much from their students if they open up the lines of communication through writing. Students will become very comfortable with writing if it is done on a regular basis. Informal writing is an excellent tool for opening this communication. It is very non-threatening and allows students to express themselves.
CHAPTER 7
FORMAL WRITING

Formal writing differs from informal writing in several ways. Primarily, formal writing requires students to answer questions that require mathematical information that is less opinionated than informal writing. Formal writing usually deals with mathematical facts more than personal opinions. Students must use prior mathematical knowledge or research to complete formal writing assignments. The following is an explanation of many of the types of formal writing assignments used in the mathematics classroom.

**Open-Ended Questions**

One of the most common types of formal writing is an open-ended question. Open-ended questions are a means to provide students with a problem-solving situation. The Illinois State Board of Education (ISBE, 1997) defines problem solving as, "the process of confronting a novel situation, formulating connections between given facts, identifying the goal of the problem, and exploring possible strategies for reaching the goal" (p. 3). Problem solving requires students to use a variety of information and strategies to solve a problem. Students are forced to think critically while finding a solution. Marilyn Burns (1995) writes, "Classroom lessons should help students learn to use a variety of strategies to solve problems, to verify and interpret results, and to generalize solutions to new problem situations" (p. 69). Open-ended questions allow students to participate in this type of learning.

Open-ended questions have a variety of solutions or a variety of methods to obtain a particular solution. These questions allow students to be more independent in their thinking. Not all students think the same way, and open-ended questions provide
students the opportunity to be unique in the solving process. Becker and Shimada (1997) state:

In traditional classroom teaching, when students are asked to focus on and develop different methods, ways, or approaches to getting an answer to a given problem and not on finding the answer to the problem the students are, in a sense, facing and dealing with an open-ended problem, since what is asked for is not the answer to the problem, but rather the methods for arriving at an answer. (p. 1)

This definition stresses the idea that the process of solving open-ended problems allows teachers to observe how students think. The ISBE (1997) stresses, "open-ended performance items that incorporate problem solving are viewed as the key to current teaching and assessing. With open-ended performance items, students spend their time exploring, investigating, reasoning, and communicating" (p. 7). Teachers can enhance learning by providing open-ended problems to their students.

When designing open-ended questions, teachers need to have their specific objectives in mind. Open-ended questions need to be designed so that they have multiple solutions or strategies. These questions should force students to think critically about the solution process, while providing them with the opportunity to justify their solution through writing. An answer is not complete without justification. Students need to show all work, including any diagrams or sketches, as well as write out an explanation of the solution process. This forces students to justify their thinking. Teachers then grade students' work using their individual choice of grading method.

Teachers need to decide how they want to evaluate open-ended questions. One of the most popular methods of grading is the use of rubrics. Teachers grade students in several different categories and assign a point value. Then, an overall grade can be
assigned after adding the points for each category. The state of Illinois uses a rubric that assesses mathematical knowledge, strategic knowledge, and communication (ISBE, 1997). Each category is assigned a score from 0 to 4. This is just one type of rubric. Teachers can design their own rubric that emphasizes their own classroom needs.

Another method of grading open-ended questions is the "piles method" (New Jersey Mathematics Coalition, 1996). When using this method, teachers place solutions in comparable piles. Teachers can then assign similar grades to papers in the same piles. This is a simple and efficient method of grading open-ended questions. Again, teachers need to decide for themselves how they want to grade open-ended questions.

Teachers use open-ended questions for various reasons. Some prepare students for standardized tests, while other use open-ended questions to evaluate students' knowledge. Whatever the reason, there are many benefits of using open-ended questions as a means for writing in mathematics class. Primarily, open-ended questions allow every student to express ideas to the teacher or class (Becker & Shimada, 1997). Instead of one student answering the question while all other students sit and listen, every student is forced to formulate a solution. This enables every student in the class to be an active participant. Even low achieving students, who would normally sit quietly, are able to respond in some manner. Dougherty (1996) writes that open-ended questions "can offer a more creative and flexible means of allowing students to respond in ways that are consistent with, and indicative of, their level of understanding" (p. 556). The entire class benefits from solving open-ended questions.

Teachers also benefit from having every student active. Teachers can evaluate student knowledge through open-ended questions. By preparing an open-ended question
that covers classroom topics, educators can evaluate student understanding. Marilyn Burns (1995) writes:

I find that written dialogues with students not only give me insights into their thinking and reasoning process but also help me revisit their thinking later. Their papers are extremely helpful for assessing their understanding and making plans for follow-up lessons. (p. 74)

Teachers can evaluate what students understand and what needs more attention in the upcoming days. Open-ended questions are an excellent assessment tool for any mathematics teacher.

Open-ended questions also allow students the opportunity to make connections while problem solving. Most problems given in mathematics class include only a few algorithms. Open-ended questions require students to use all of their mathematics knowledge to find a solution. Students must organize their thoughts and use their desired strategies to solve problems. Open-ended questions are usually broader in scope and require an integration of student knowledge. The ISBE (1997) states, “By inventing their own ways to solve problems, students are more likely to become engaged with the subject matter and develop a deeper understanding of the learning domain” (p. 4).

Students are encouraged to use comprehensive knowledge of mathematics.

Open-ended questions also require students to compare and modify ideas. When a class is asked to solve an open-ended question, many students will do the problem differently. When teachers have students share these ideas with the rest of the class, students are able to learn by seeing other student discoveries or methods (Becker & Shimada 1997). Students see that they are diverse and unique. They also learn from their
peers by comparing multiple ideas. Open-ended questions show students that there are multiple methods or solutions for some problems.

**Formal Papers**

Another type of mathematics writing is a formal paper. Teachers can assign topics for students to research. Students then write a paper that summarizes the information. Carter and Carter (1994) write, “Standard essays with an introductory thesis, body, and conclusion not only require math students to organize their ideas carefully, but also allow them to show what they know about the concepts they are learning” (p. 23). Students are allowed to combine known information with their research topic. This enables them to explore interests as well as integrate previous knowledge by writing.

Formal papers also require students to research topics that relate mathematics to real world situations. Students can find topics that interest them outside the mathematics classroom. Students who enjoy art can research the works of M.C. Escher (Countryman, 1992, p. 66). Musicians can explore topics such as Pythagorean harmony. Other topics may include mathematician biographies, developments in technology, careers in mathematics, or book reports (Rose, 1989, pp. 18-19).

Teachers who require students to write formal papers may want to follow some of the following tips. Countryman (1992) writes that she has the class brainstorm for ideas to introduce the assignment. Next, students pick an individual topic to research. Many teachers take their classes to the library for this research. After students begin writing, class time can be used for peer-editing. Carter and Carter (1994) believe that teachers need to decide in advance how they are going to grade these papers. Students need to know what is expected of them before they start writing. Manning and Manning (1996)
believe that the key to successful papers is an abundance of research materials. Students should have access to books, magazines, videos, tapes, internet, and real objects. When teachers follow these steps, the use of formal writing can be an excellent teaching and learning tool.

**Student Authored Textbooks**

Teachers can also have students author their own textbooks. This provides a very unique opportunity to write in the mathematics classroom. Assignments can vary drastically. Some educators have made this project a year long task, with the final project being an entire book. Others wait until the end of the year and use writing as a review for the semester. Others may only require a chapter to be prepared by students. Teachers need to decide how extensive they would like their writing assignment to be.

The process of a student-produced textbook is very unique. Teachers give students the requirements for the project, and then student creativity takes over (Montague, 1973). In groups, students research topics that need to be summarized in their books. When students understand their topics, they explain, in their own words, how to complete the mathematical tasks. Students provide written text, example problems with explanations, problem sets, chapter tests, and any other activities. Students are also responsible for a solution manual for any problem sets or tests. Students write their sections and peer-edit them in class. Next, the teacher collects the student work and edits. Students produce a final draft when all editing is complete. The final text is distributed and students learn from one another. When finished, this textbook can be an excellent teaching tool.

Student authored textbooks have many benefits. Primarily, students are challenged to learn new material on their own (Montague, 1973). Students become
responsible for their own learning. They must research topics and write explanations in their own words. This provides students an introduction to research that will benefit them throughout education. Sosenke (1994) writes that having students author their own textbooks allow them an “opportunity to understand their thinking and to recognize more effectively the areas with which they experienced the most difficulties” (p. 111). This activity can be a great learning experience for students. Students not only learn mathematics, but also learn their strengths and weaknesses as active learners.

Student authored textbooks allow students to work cooperatively on an assignment. Montague (1973) believes that individual talents benefit the whole of the class. Artistic students can design the book, while students with strengths in grammar can peer-edit and enhance writing. Students with mathematical talent can assist others with the mathematical content. Students are all actively working as a group to accomplish a common goal. When students finish, they will feel a sense of pride for accomplishing such a task. Teachers can also benefit from having students write their own textbook. This type of activity offers a variation from the traditional mathematics classroom. Teachers who have taught the same way for several years may want a change of pace. This activity provides teachers with a new outlook on teaching. Teachers can also learn a lot about their students with this type of writing assignment. While discussing her students who were preparing a chapter on factoring, Sosenske (1994) writes, “It gave me deep insights into my students’ understanding of algebraic concepts while being a more accurate and extensive way to assess their learning” (p. 109). Teachers can assess student knowledge while observing how students work together. Teachers can witness student strengths and weaknesses during this activity. When implementing this type of writing activity, both students and teachers benefit.
Question Writing

Another type of formal writing is question writing. Teachers can have students write questions for other students to answer. This allows students to find out what they can and cannot do in mathematics. If students can write questions about a topic, then they fully understand this topic. If students struggle to write questions, they probably do not fully understand the concepts. This provides an opportunity for teachers to assess student knowledge. Rose (1989) writes that students focus on what they do not understand when they are allowed to write questions. She also believes this process allows students to reduce math anxiety as well as transfer confusion onto paper. Students can express themselves by writing these questions. This process opens the line of communication between teachers and students. Teachers can use these questions for class discussion or even put them on homework or tests.

Note Taking

Note taking is another in-class writing assignment that is done in mathematics. This is probably the most common type of formal writing that occurs in mathematics. Most teachers require their students to take notes every day. Teachers have students write notes so they have a written record of what takes place in class. Notes also summarize a topic that is being discussed. Rose (1989) writes, "They [students] tend to retain the information longer since they engage in multi-representational learning, and they have a written record for later referral" (p. 21). By taking notes, students remember information better. When students are asked to write information, it is presented to them in a different way. Many students will benefit from this experience. Note taking also gives students a source of review. When students forget how to solve a problem, they
can look back at their class notes. This enables them to review material that they have forgotten.
CHAPTER 8
WRITING IN MATHEMATICS: A COMPARISON

A comparison study was done to examine the effects of writing on mathematics performance. The study took place during the fall semester of the 1999-2000 school year. Participants in the study were pre-algebra II students from Mattoon High School. The study began the first day of school and concluded just before the end of the semester. Three sections of pre-algebra were studied using a variety of writing prompts in order to study the effects of different types of writing.

The students involved in the writing study were mostly sophomores in high school. A few were juniors or seniors. Pre-algebra II is the second class in a series meant to prepare high school students to take algebra. These are students who have struggled with mathematics and need extra support to be successful in high school mathematics. Students fulfill their graduation requirements with this class, but many take the next step to algebra. Pre-algebra II prepares them for this endeavor.

Pre-tests

The study began with every student writing a mathematics autobiography on the first day of school. This assignment was started in class and finished as a homework assignment. On the second day, students completed a math anxiety questionnaire. Students answered various questions that pertained to their attitudes toward mathematics. The test (Table 1) was retrieved from the World Wide Web in August of 1999. The math anxiety test was written by Professor Freedman of Camden County College <http://www.geocities.com/~mathskills/anxtest.htm>. Students were given a statement and then responded by selecting a number 1 through 5 that determined the degree that they agreed or disagreed. When the students finished, the tests were scored to determine
the degree of math anxiety a student may have felt. The test was used to compare
students with one another as well as themselves at the end of the study. Table 1 displays
the math anxiety questionnaire.

<table>
<thead>
<tr>
<th>Math Anxiety Questionnaire</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I hate math.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. Math isn’t so tough now, but it’s going to get really difficult soon.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3. I tune out in math class. I don’t mean to do it, but I do.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. I don’t really like asking my math teacher questions.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5. I panic when called on in math class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. I worry much more about math tests than any other kind of test.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7. I can’t wait until I don’t have to take any more math.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Find the total of all numbers you circled.

On the third day of class every student was given a worksheet with four open-ended questions. Students were told that the questions would be graded according to the Illinois State Achievement Test rubric. Students would receive three grades for each question. They were graded for mathematical knowledge, strategic knowledge, and communication. Emphasis was placed on the communication aspect of the solution, because of the general lack of writing in most mathematics classes. Students were shown a sample question with an answer and shown the grading process for that particular
question. After asking various questions, students completed the worksheet. The solutions were each graded using the rubric that is shown in Table 2.

Table 2: Mathematics Scoring Rubric

<table>
<thead>
<tr>
<th>MATHEMATICS SCORING RUBRIC: A GUIDE TO SCORING OPEN-ENDED ITEMS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SCORE LEVEL</strong></td>
</tr>
<tr>
<td>-----------------</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td>3</td>
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<tr>
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<td></td>
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<tr>
<td>2</td>
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<tr>
<td></td>
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<tr>
<td></td>
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<tr>
<td>1</td>
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<td></td>
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<tr>
<td></td>
</tr>
</tbody>
</table>

When students finished this open-ended worksheet, they had completed the pre-test portion of the writing comparison. These results would be compared to similar tests administered at the end of the fall semester.

The Writing Process

After the pre-tests were administered, each of the three classes had different agendas throughout the semester. Class 1 was the norm group. This class was taught with no writing throughout the semester. This class was taught using a lecture-discussion
type of teaching technique. Students received instruction that is common in most high school mathematics classrooms. The new material was discussed, the teacher went through several examples, and then the students received a set of problems to complete. There were no questions that involved writing throughout the entire semester.

The second class was taught the exact same material, but students were required to write in a mathematics journal three days a week. Every student was given a spiral notebook that remained in the classroom at all times. On journal writing days, students were given their journals and asked to answer a prompt that was written on the overhead projector. Students spent the first five to ten minutes of class time writing their responses to the prompts. The teacher read all new journal entries each weekend. Responses were written to each entry and given back to the students on the next writing day. This process continued for the entire semester.

The third class was also taught the same mathematics information. In addition, this class was given an open-ended question to answer two days a week. These questions covered information that was being studied at the time. Students would begin many class periods by reading and responding to an open-ended question. These problems were all finished in class. The questions were then graded using the rubric in Table 2. Student work was returned the next day, and exemplary student work was shared with the rest of the class. This enabled students to see examples of quality work to model the next time. This also allowed for students to realize that more than one method or solution was possible. Students could learn from each other during this process.

Although each of the classes varied slightly, the same curriculum was used in every class. Each class was given a different type of writing prompt so that the results could be compared with each other. The two classes that did writing could be compared
with the one that did no writing at all. The following is an explanation of these results and conclusions that can be drawn from this study.
CHAPTER 9
MATHEMATICAL AUTOBIOGRAPHIES: AN INTRODUCTION TO WRITING IN THE MATHEMATICS CLASSROOM

Students in all three classes wrote mathematical autobiographies the first day of the school year. This was done for two reasons. Primarily, it was a tool to introduce writing in mathematics class. Most students had no experience with this type of assignment. This prepared them for a semester full of expressing their thoughts and ideas through writing. The other reason for using autobiographies was to gather information about students. Students were given several prompts that they could answer. Students were asked to write about when they first remembered learning mathematics, whether they liked or disliked mathematics and why, any failures or triumphs, strengths and weaknesses, learning styles, family opinions of mathematics, and any other information that they would like to share about themselves and learning mathematics. Students were asked to write at least a page about themselves and their learning history. The assignment was started in class, and students were required to finish for homework. Students were given a completion grade to start the school year.

When reading the autobiographies, a great deal of valuable information was discovered. Students provided insights into their learning as well as explanations as to why they succeed or fail at different times. Students discussed teachers that they liked or disliked with an explanation explaining their reasons. Many students discussed personal family information that they felt important. A few students even explained the actual moment that they started to dislike mathematics. Autobiographies allowed the students to communicate effectively with their new mathematics teacher. The information
gathered allowed for the teaching and learning environment to be adapted in order for everyone to learn effectively.

The following are examples of student writing. These samples display much of the valuable information that was gathered from this assignment. An explanation follows each example. One student wrote:

I didn’t really dislike math until 4th grade and had to learn division and multiplication. I could never think of the answer quick enough or how to divide. The teacher tried to teach me but whenever I don’t understand I’m always afraid to ask the teacher. I finally figured it out and could do short division until I had to learn long division. I caught on quicker to long division, but I still have some trouble. In 8th grade we had to learn algebra, but it confused me. Word problems confuse me too. Most of my teachers didn’t explain it as good as I need it explained so I get confused and I’m afraid to ask the teachers. I still get confused by measurements. Conversions are the worst for me. I usually can’t do fractions without a calculator. Mental math is hard because I can’t remember all the numbers, especially if there’s a bunch of different problems together.

This student provided some very valuable information that would have remained unknown to the teacher without a mathematical autobiography. This student recalls the exact moment that she began to dislike mathematics. This was a common occurrence in many of the autobiographies. As soon as they have one bad experience, they start to dislike mathematics. This student also provides valuable information about asking questions. She states that she is afraid to ask questions during class. Once a teacher learns this characteristic, he or she can teach accordingly. The teacher could ask this student if she understood when there was free time at the end of the class period, and not
just assume that she understood since she was not asking questions. Lastly, this student gives specific examples of topics that she has struggled with in the past. She does not understand algebra and has difficulty understanding measurements and conversions. By knowing this from the start of the year, the teacher can be prepared to provide extra assistance when these topics are covered. This autobiography gives the teacher information that will make teaching much more effective throughout the semester.

Another student wrote:

I like math. It's just that other people work at different speeds than others. Also, it takes me a little more time to comprehend all the details and calculations. I know I'm not the best mathematician, but I'm not the worst either. The reason I'm not the worst is because I have aced a couple tests in my lifetime. Then again, I have bombed some too. One disaster happened last year. I was in a regular algebra class, but I didn't comprehend some things so my grade went down. My teacher told me if I did good on my exams my grade would be a C. If I didn't, it would be a D. Unfortunately, I got the lower grade! That's just one of my many math disasters. When I am trying to learn a new concept, I like to do visual work. That's one of my favorites. I like when we play games to help us learn the techniques.

This student liked mathematics although she had some trouble in the previous year. She explained that she learns at a slower pace than many of the other students, and this probably had something to do with her getting a D in algebra. She also took the opportunity to explain that she had been successful at other times in mathematics. Teachers can use this information to monitor student progress. The teacher could monitor this student and slow down if necessary when explaining new material. This
student also describes how she learns most effectively. She explains that she enjoys learning mathematics by doing visual types of activities. When teachers discover this trend, they can plan activities that use mathematical manipulatives. Students who are visual learners will comprehend new material much easier with this technique. When students can express this information through writing, teachers can prepare lessons that teach every student effectively.

Autobiographies can also provide information outside of mathematics. Teachers can learn about a student’s family through writing. One student wrote:

I really dislike math because of past events. I never really had a math triumph that I can remember. Maybe it was just passing the class. I don’t know. Well, a disaster would be getting an F. Well, I never really liked math but I know on a personal level, I am going to need it in the future and so I still need to learn more. I don’t really remember using math because I was never a math child. I was an artist or technician. No one ever helped me at home because I was left alone too much. My life really stunk because most of my life no one helped me or thought about me. So, basically nobody cares.

Although this student does not write much about mathematics, he gives a lot of personal information. This student probably wants people to listen and help him. This entry informs the teacher of this need for attention. Teachers can learn a great deal about a student’s life through autobiographies. Students will offer information that want to share but are afraid to say in person. This student has opened a line of communication with his teacher on the first day of school that can be continued throughout the school year.
All of these entries provided valuable information to the teacher. Autobiographies opened the lines of communication in a classroom on the first day of school. The teacher could read these personal histories and teach mathematics to everyone. Some students need extra help, some move at a slower pace, and some are even terrified of learning new material. Autobiographies allowed students to explain these concerns before being taught any new topics. Students also had the opportunity to vent some of their frustrations. This enabled them to explain why they may have been placed in pre-algebra II in the first place. The activity improved the learning environment drastically by allowing students to express their ideas and opinions about learning mathematics.
CHAPTER 10
JOURNAL WRITING

One of the groups involved in the writing in mathematics study was required to write in a journal three times a week. When the process began, it was difficult to get students to write a lengthy entry. Students wanted to write only a few sentences and be done in only a few minutes. The students were very reluctant to write about their feelings and ideas. As time passed, entries improved and students enjoyed receiving feedback in their journals. Students began to write more each week. Some students even looked forward to the days in which they wrote in their journals.

Many different types of prompts were used during the semester. A list of sample journal prompts is provided in Appendix A. Some entries required students to answer mathematical prompts. With this type of prompt, students were asked to write about how to solve a problem and the steps involved. Another type of prompt dealt with learning processes. Students were asked how they study for tests, prepare homework, or like to learn new material. Students were encouraged to write about different strategies that they implement in mathematics classroom. The last type of prompt was attitudinal prompts. These allowed students to answer questions about themselves, their families, their interests outside of class, and any other types of information that they wanted to provide. Students always had the option to write about something other than the given prompt if they had something that they really would like to share with the teacher.

When reading the students’ entries, it was interesting to discover how much personal information students would share when given an attitudinal prompt. Some entries discussed relationships with boyfriends or girlfriends. Others described what had happened at home on specific nights. Some students used journals as a way to
communicate their problems. Many of these students must not have had someone to
discuss these topics with other than the teacher. It was amazing how much these students
would “open up” when given the opportunity to write.

Other students would write about interests outside of school. Some students
discussed interests and experiences in athletics. Students were eager to write about
accomplishments in hockey, soccer, hunting, football, basketball and many other sports.
Other students wrote about involvement in school clubs. One student was always eager
to write about her participation in acting. Some students wrote about what they liked and
disliked about school. Others stated what they thought should be changed about the
mathematics class. By reading these entries, it was easy to discover the hobbies and
interests of each student. Journals opened the lines of communication and allowed for
the teacher-student relationship to become much more significant.

Valuable information was also gathered when students were given process
prompts. Students were required to write about how they learned mathematics. It was
surprising to find that most students never studied for mathematics tests. Most students
wrote that there was no way to study for mathematics. They had the feeling that students
either understood the topics or did not. There was no way to teach oneself by studying.
This idea was addressed early in the year. When this information was discovered,
studying techniques were discussed. The journals allowed for information to be
exchanged from the students to the teacher. Then, the teacher could correct many of the
misconceptions.

Students were also willing to discuss how they liked to learn mathematics.
Students frequently wrote that they really dislike when a mathematics teacher would
stand at the front of the room and lecture. Many students stated that they learned much
more effectively when they were allowed to learn by doing hands-on activities. Other students stressed that they learned better when they were allowed to work with a partner or group. They liked to have the opportunity to learn and teach one another how to solve mathematical problems. One of the most common questions that was addressed asked, “When will we ever use this?” Students wanted to solve problems that related to real world examples. They disliked problem sets that had no meaning to them. They wanted a problem that could be discussed and modeled.

Teaching could be drastically modified after learning all of this information. Journals provided students an opportunity to express their ideas. They could take some control of the learning environment. By doing this, class became much more interesting and valuable to the students. They could learn in the best possible method. Journals allowed them to communicate their ideas to the teacher.

The mathematical prompts were also very beneficial to both the students and teacher. When given a mathematical prompt, students had to solve the problem and then explain their process. This gave very valuable information to the teacher. After a topic was covered in class, a sample problem could be given as a journal prompt. Students would answer the question, and that night the teacher could evaluate the student work. The written explanations allowed the teacher to see who had a full understanding of the topic. Many times, a student can complete a problem but have no idea of the reasoning behind it. By having students write out an explanation, the teacher can check for complete understanding. Many students could do the problem, but had no idea why the algorithm worked. This was addressed during the next class period. Journals allowed the teacher to evaluate and assess student understanding throughout the school year.
The journals were a valuable teaching tool during the study. Information that aided instruction and communication was easily obtained. Once students became comfortable with the idea of writing, it was a very beneficial activity. There was also a much better relationship with this group of students. They were much more willing to stop and talk in the hallways than most of the other students. A line of communication that benefited both the teacher and the students started with the use of journals in mathematics class.
CHAPTER 11
SOLVING OPEN-ENDED QUESTIONS

The class that was asked to complete open-ended questions on a regular basis was also reluctant at first. Appendix B lists many of the open-ended questions that were used during the study. Students did not want to write out a detailed explanation for each step of the problem. Students did not mind doing the mathematics but were not acquainted with the task of showing their work and explaining the process. All of the students struggled at the beginning of the study. As the year progressed, students began to do very well on these questions. One of the major reasons was the positive reinforcement of quality work. After the problems were graded and returned, the best papers were displayed for the class to observe. Students were asked to explain their solutions to the rest of the class. These excellent examples could serve as models for the rest of the class. Once students realized what was expected of them, they began to be very successful at solving open-ended questions.

Students also realized that they were being assessed on more than one technique. Students discovered that even if they were not completely correct with the mathematics, they could still receive credit for showing their work and explaining the process that they used. Students could be successful without solving the problem correctly. This helped many of the students feel more at ease when solving problems. They were so accustomed to the idea that they would fail if they did not find the correct answer. This process allowed for them to feel more comfortable solving complex problems.

Students were also relieved to find that there could be more than one answer to a given problem. They were excited to find out that each of the problems could be solved a multiple of ways. This also lessened the math anxiety that was previously present.
Students could be unique in their solution process. They could draw pictures or diagrams to assist them if necessary. Some students would solve problems by using algebra, while others would use a guess and check type of method. Either way was acceptable as long as the students explained their unique process. This process allowed for the students to use creativity when solving mathematics problems.

Open-ended questions also forced students to organize their thoughts when they solved problems. Many students do not know where to begin when solving a mathematical problem. When students are required to show their work and explain the process, they are forced to organize the information. Open-ended questions forced students to think more critically before solving the problem. Students had to think through their ideas in order to complete the task. This aided students in the process of solving open-ended questions.

The same open-ended questions were given as the pretest and the posttest for this study. This allowed for a comparison to be made of student work. When reading the student responses, it was very clear that students improved before the study concluded. The following are examples of student solutions to some of the open-ended questions.

One student answered:
Question 1: Joe said that he worked 400 hours last month. Does this sound reasonable? Why or why not?

<table>
<thead>
<tr>
<th>Pre-test Answer</th>
<th>Post-test Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>There is not enough info. to answer the problem.</td>
<td>No, it doesn't seem reasonable because a normal work week is 40 hrs which leads to 160 hrs. a month. If you worked 400 hrs in a month, you would have to work 100 hrs. a week.</td>
</tr>
</tbody>
</table>

A great difference exists between the answer written on the pretest and the answer written on the posttest. The student does not work out the problem at all in the pretest. He just regards the question as trivial and provides no work or explanation of a solution.

The answer on the second test is much more detailed. The student thinks about the problem and works out some of the computations that are necessary to make a decision.

This student also explains his answer very well. He states his answer and then explains why he believes this to be true. By practicing this type of problem throughout the semester, the student was able to provide better explanations for his problem solving.

Another student solved the next problem in the following manner:

Question 3: A taxicab charges $1.25 for the first mile plus $.75 for each additional mile. If John paid $5.75 for a ride in one of this company’s taxi cabs, how far did he travel?

<table>
<thead>
<tr>
<th>Pre-test Answer</th>
<th>Post-test Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 miles because I took 1.25 out of the total + counted it as one mile then divided 4.50 by .75</td>
<td>$5.75 - 1.25 = 4.50. That took away the first mile. Then to get the rest of the answer I took $4.50 and divided it by .75 to figure the total amount of miles to be 7.</td>
</tr>
</tbody>
</table>

To get this answer, I first took $1.25 away from $5.75. This gave me $4.50. Then to get the rest of the answer I took $4.50 and divided it by .75 to figure the total amount of miles to be 7.
Again, this student improved drastically over the semester. When completing the pretest, the student solved the problem incorrectly. She found the answer to be 5 miles rather than 7 miles. She explained some of the solution process, but the explanation was lacking much of the required information. She also did not show any of the work that she used to solve the problem. The posttest, on the other hand, has a very specific explanation. The student shows the algorithm that was used during the solution process. Although the order of operations she uses is incorrect, she explains what she did and why. Her explanation tells the reader exactly what thought processes that she was using while solving the problem. She also finds the correct answer this time. Her solution, strategy, and explanation are all very well written in the posttest example.
CHAPTER 12
COMPARISON RESULTS

The scores from the pretests and posttests provide some valuable information about the effect of writing in mathematics class. These scores allow for a comparison between scores before students were required to write in class and then after the study was completed. Students answered the exact same questions on both tests. The following is a discussion of some of these scores.

Anxiety Test

Table 3 shows the anxiety test scores for the group that did no writing in the classroom. Student names are not used, but each student is assigned a letter. The student response is listed for each question on both tests. The total score from each test is also calculated. At the end of each table, the class average and standard deviation are also listed for each test. Table 4 has the same information for the class that was required to keep a journal in class, while table 5 contains the information for the class of students that answered open-ended questions.

The most obvious information from the data shows that the class average increased in all three study groups. This means that anxiety decreased since a low score implies high math anxiety while a high score implies low math anxiety. While some students show great differences in their scores, some differed only slightly. Many students showed less math anxiety while some reported having a higher level of anxiety. The statistics are somewhat inconsistent with the aforementioned literature. Writing in mathematics class did not provide a drastic change in math anxiety. As a whole, the classes showed an increase in scores which implies a decrease in math anxiety, but this could be explained by various reasons. The material covered in the class or slow pace
<table>
<thead>
<tr>
<th>Student</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
<th>#7</th>
<th>Pre Total</th>
<th>Post Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Pre</td>
<td>3</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>21</td>
</tr>
<tr>
<td>B</td>
<td>Pre</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>26</td>
</tr>
<tr>
<td>C</td>
<td>Pre</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>5</td>
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<td>28</td>
</tr>
<tr>
<td></td>
<td>Post</td>
<td>5</td>
<td>5</td>
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<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>35</td>
</tr>
<tr>
<td>D</td>
<td>Pre</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>5</td>
<td>19</td>
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<tr>
<td></td>
<td>Post</td>
<td>4</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>5</td>
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| Mean    | 17.52941 | 21.70588 |
| Standard Deviation | 5.088193 | 3.396076 |
### Table 5

**Math Anxiety Results**

**Open-ended Question Class**

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Mean: 20.84615 24.61538

Standard Deviation: 5.382784 3.228479
could account for some of these decreases in anxiety. Student attitudes on test days could also account for varied results. Overall, writing did not seem to effect students drastically in this aspect.

**Open-Ended Questions**

The results from the open-ended tests are listed in tables 6 through 8. Table 6 provides the results from the class that did no writing. Table 7 shows the scores from the journal writing class, and table 8 shows scores from the class that answered open-ended questions routinely. The names are also not included in these tables, but students are assigned the same letters as the other tables. Scores from both the pretest and posttest are given for each question. The individual scores for mathematical knowledge, strategic knowledge, and communication are each listed. Scores are tallied to give an overall score for the test. Class averages and standard deviations are also calculated for each class.

The scores from these tests show great improvements from students who completed this type of problems throughout the semester. Students who did no writing in class showed the least improvement from pretest to posttest. The average score for the posttest actually declined from that of the pretest. The average pretest score was 28.19 out of a possible 48 points. The average dropped to a 26.31 on the posttest. Out of the twenty students in this class, only ten improved their scores during the study. The other ten students had scores that declined. When looking at the scores for each individual problem, it is evident that many of the mathematical knowledge scores improved. This can probably be attributed to the students gaining mathematical knowledge throughout the semester. Students, as a whole, improved slightly on the strategy scores, but their
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Open Ended Questions  
Control Group

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C = COMMUNICATION  

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Journal Writing Class

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Mean: 23.28571 39.57143

Standard Deviation: 7.321502 7.743129
scores for communication did not improve much at all. These students had great difficulty explaining the processes that they used to find a solution. It is evident that these students did not improve their scores on the open-ended portion of the posttest because they were not accustomed to writing in mathematics class.

The group of students that kept a journal improved their average score on the posttest. These students had pretest scores similar to the group that did no writing in class. This class improved on the posttest though. The pretest average for this class was 27.88. The posttest average score was 31.19. The average score raised by 14 percent. Twelve out of the seventeen students improved their individual scores over the study period. This class raised its mathematical and strategic scores, but also raised many of the communication scores. This is probably due to their experience with writing in their journals.

The class that was required to solve open-ended questions throughout the semester improved drastically from the pretest to the posttest. The class average on the pretest was 23.29 out of a possible 48 points. The posttest average score rose to a score of 39.57. The scores increased by 27 percent. Each of the fourteen students in the class improved from the pretest to the posttest. This can be attributed to the experience gained throughout the semester. These students knew exactly what was expected of them on this type of question. Students had experience solving open-ended questions and had the opportunity to see models of acceptable work weekly. Students knew how these problems were to be graded and in turn were willing to explain their solution in writing. These students became very comfortable solving these types of problems, and this is apparent when looking at their scores.
Final Exam Scores

All three classes took the same final exam at the end of the semester. The final exam scores for each class are listed in table 9. Although there was no pretest, these scores also support the idea that writing improves mathematics learning. The class that did no writing had an average final exam score of 82.5. The journal writing class performed slightly better, averaging an 83 on the exam. The open-ended question class outperformed everyone by scoring an average of nearly 87.5 percent. These scores support much of the literature discussed earlier in this paper. Students were able to perform better on a final exam when learning the material by writing in mathematics.

Table 9:

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Final Thoughts

Writing in mathematics class was very beneficial to both students and teacher. Although some of the statistics of the study may not support some of the aforementioned literature, the practice of writing improved the learning environment. Students who wrote in journals were able to communicate daily. This opened the lines of communication between the students and the teacher. Although students were reluctant to write in the beginning of the semester, everyone benefited from this experience as time passed. These students were very willing to stay after class and discuss different aspects of their lives. The relationship between teacher and students was much closer with the journal writing group than any other class.

The open-ended question group also benefited from writing in class. These students became very comfortable explaining their solution process. By the end of the semester, most students would write a paragraph to explain their answer when asked to do so. These students found that they understood the material much better after they explained it in writing. Teachers who want their students to justify solutions may want to try using this type of problem solving in their classrooms. This is also excellent practice for standardized tests like the Illinois Standard Achievement Test. If teachers want students to answer these questions more effectively on these tests, they need to allow time for students to practice and receive feedback on this type of problem. In general, these open-ended questions forced students to justify their work as well as open the lines of communication in the mathematics classroom.

This study was an excellent opportunity to learn about students and writing in the mathematics. Writing is a valuable tool for teachers to use in their classrooms. This
summary of writing will hopefully allow teachers to implement some of the mentioned strategies in their classrooms. Further studies could be done to test the effectiveness of writing on learning mathematics. It would be interesting to see how writing affected different types of students. The students in this study were low achieving mathematics students. Students with better mathematics skills may have much different results than this study. This is a study that could be done in the future. It would also be interesting to use a different anxiety test than the one used in this study. Another adaptation of this study could be the use of different types of writing. Students could be asked to do writings other than open-ended questions and journals. No matter what type of writing is done, educators will find that writing in mathematics is an excellent teaching tool for any classroom.
APPENDIX A: JOURNAL WRITING PROMPTS

The following is a list of journal prompts used during the writing in mathematics comparison.

1. My goals for this class are...
2. What did you like most/least about your last math class?
3. Draw a mathematician and explain what a mathematician does.
4. Explain how to evaluate 3+10/2-7 and why.
5. My parents feel that math is ...
6. What part of this chapter do you understand the least?
7. Write everything you know about area.
8. How did you use math this weekend?
9. Write about any topic you want me to know about.
10. What do you want to be in 10 years?
11. Why is it important to learn mathematics?
12. Write instructions about how to solve 5x + 2 = 17.
13. Explain how to graph the equation y = 3x + 2. Include y-intercept and slope in your explanation.
14. Write a test question for tomorrow’s test.
15. What grade do you think received on yesterday’s test? Why do you think this is true?
16. How do you study for a math test?
17. Explain mean, median, mode, and range.
18. How do you use probability in your life?
19. What would you change about this class?
20. I feel that I am a _________ math student because …
21. If you were a shape, what shape would you be?

22. What do you like most about high school? Least?

23. What is your favorite number and why?

24. What do you think about standardized tests like the ISAT?

25. Explain how to multiply the fractions 1/5 and 4/9. How would you add them?

26. Why do we need to use scientific notation?

27. What are your plans for the weekend?

28. What is your favorite part of this class?

29. Are you happy with your quarter grade? Why or why not?

30. How do you use math when driving a car?

31. How do you find the volume of a cone?

32. What is surface area?

33. When will you use mathematics in life?

34. When I hear someone say math is fun, I …

35. Draw a cartoon using any of the shapes we used in this chapter.

36. Write your definition of a quadrilateral.

37. What is the difference between acute, right, and obtuse angles?

38. What do you need to do to be successful in mathematics?

39. Which fraction is bigger 1/3 or 1/5? Why?

40. What advice would you give someone taking this class next year?
APPENDIX B: SAMPLE OPEN-ENDED QUESTIONS

1. Joe said that he worked 400 hours last month. Does this sound reasonable? Why or why not?

2. Estimate 4.56 x 31 in your head. Explain in writing what your estimate is and how you found it.

3. A taxicab company charges $1.25 for the first mile plus $.75 for each additional mile. If John paid $5.75 for a ride in one of this company's taxis, how far did he travel? Explain how you got your answer and why you did the work you did.

4. Samantha bought some paperback books for $5 each and some magazines for $3 each. She paid a total of $32. How many of each did she buy? Explain how you found your answer and why you solved it that way.

5. An activity class for children was held last Saturday, and 20 children attended. The instructor brought 12 apples and 15 bananas as a snack for the children. One helper passed out the apples to the students while another helper passed out the bananas. Every student received at least one of the fruits. If all the apples and bananas were given out, how many students go more than one fruit? Show all of your work and explain in words how you found your answer.

6. You are in charge of setting up a room for an awards banquet. The school has tables that seat either 8 or 10 people. No empty seats are allowed. How many of each size table will you need to use to make sure everyone has a seat? Show all of your work and explain in words how you found your answer.

7. John went to the store to buy some tapes and CD's. It cost $7 for each tape and $12 for each CD. If he spent $109, how many tapes and CD's did John buy? Show all of your work and explain in words how you found your answer.

8. A store sells a box of 5 frozen yogurt bars for $1.20. The same store sells a box containing 7 bars for $1.59. Which is the better buy? Show all of your work and explain in words how you found your answer.

9. Paul is six years older than Pat, who is two years younger than Shelley but taller. Paul is eighteen years old. How old is Shelley? Show all of your work and explain in words how you found your answer.

10. Caesar and Cleopatra were paid $.05 for each medal they polished. At the end of two days, Cleopatra had polished twice as many as Caesar. At that time, they had earned $17.10. How many medals did Caesar polish? Show all of your work and explain in words how you found your answer.
11. Diana is going to drive her car from Seattle to Kansas City. The distance between the two cities is 1800 miles. Diana drives a car that gets 30 miles per gallon. If a tank of gas costs $1.19, how much will Diana spend on her trip to Kansas City? Show all of your work and explain in words how you found your answer.

12. John has the option to buy some land as an investment. He can buy 10 acres of land for $100,000.00. He figures that he can make a subdivision out of this land if he divides land so that he can put 4 lots on each acre. He can then sell those lots for $10,000.00 each. Should John make this investment? Show all of your work and explain in words how you found your answer.

13. Burger Land has only one restaurant and employs 5 people at all times. It claims it sold 4,000,000 burgers last year. Does this sound reasonable? Show all of your work and explain in words how you found your answer.

14. A soccer team plays a 30 game season. The team receives 3 points of a win, 1 point for a tie, and 0 points for a loss. At the end of the season, one team ends up with 68 points. They also tied more games than they lost. What could their record be for this season? Show all of your work and explain in words how you found your answer.

15. You record grades for a quiz. There are 8 students in the class. Students can earn from 0 to 5 points on this quiz. Make up these 8 scores so that the mean, mode, and median are all different numbers. Explain why your data is correct. Show all of your work and explain in words how you found your answer.
BIBLIOGRAPHY


<http://www.math.iupui.edu/writing_in_math/guide.html>


<http:ehostvgw15.epnet.com/fulltext.asp>


