THE EFFECTS OF WRITING-TO-LEARN TASKS ON
ACHIEVEMENT AND ATTITUDE IN MATHEMATICS

DISSERTATION

Presented to the Graduate Council of the
University of North Texas in Partial
Fulfillment of the Requirements

For the Degree of

DOCTOR OF EDUCATION

By

Beverly Robinson Millican, B.A., M.S.
Denton, Texas
May, 1994
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The problem of this study was to determine the effects of implementing writing-to-learn tasks in mathematics instruction on fourth grade students' achievement and attitude toward mathematics. Also addressed in this study is whether or not achievement and attitude measures of female students and low achieving students are effected by the use of writing in mathematics.

Fourth grade mathematics teachers and their students from two closely matched elementary schools in a large suburban school district in North Texas participated in the study. The treatment group consisted of four teachers and 125 students; the contrast group consisted of four teachers and 118 students.

The teachers in the treatment group were provided with staff development, modeling, and support in using writing-to-learn techniques in mathematics. Teachers in the treatment group involved their students in writing activities in mathematics for a ten week period.

Student achievement was measured by a mathematics criterion-referenced test, administered as both a pretest and posttest. Attitude was measured by the Survey of School Attitudes, with Form A as the pretest and Form B as the posttest.

Following the treatment, achievement and attitude measures were analyzed using analysis of covariance, with the pretest scores as the covariant. Significant differences in achievement were found between the treatment and contrast groups. In addition, significant differences were found in achievement
measures of the female students and low achieving students who used writing in mathematics, as compared to the female students and low achievers in the contrast group. No significant differences in attitude toward mathematics was found.

Recommendations for future research include examining the effects of writing-to-learn in mathematics at other grade levels, measuring cumulative effects of long term usage of mathematics writing tasks, using performance-based assessments instead of more traditional assessments to measure achievement, and concentrating on one type of writing in mathematics, such as expressive.
### CONTENTS

**LIST OF TABLES** ........................................................................................................ iv

**Chapter**

1. **INTRODUCTION** ..................................................................................................... 1
   - Background and Significance of the Study
   - Need for the Study
   - Overview of Research Design
   - Statement of the Problem
   - Hypotheses
   - Definition of Terms
   - Limitations

2. **REVIEW OF RELATED LITERATURE** ................................................................. 14
   - Writing-to-Learn
   - Writing-to-Learn in Mathematics
   - Types of Writing and Use of Each in Mathematics Instruction

3. **METHODOLOGY** .................................................................................................. 47
   - Selection of the Population
   - Instrumentation
   - Research Design and Treatment
   - Treatment of Data

4. **PRESENTATION AND ANALYSIS OF DATA** .................................................... 59

5. **SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS** .................. 68

**APPENDIX A**: TAAS Mathematics Diagnostic Test .................................................. 77

**APPENDIX B**: A Fourth Grade Writing Lesson: Investigating Geometric Terms Using Alphabet Letters .................................................................................. 97

**APPENDIX C**: Examples of Transactional, Expressive, and Poetic Writing-to-Learn Tasks in Mathematics .................................................. 100

**REFERENCES**: ......................................................................................................... 104
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. District and Academic Excellence Indicator System Demographic Data Used to Match Groups</td>
<td>48</td>
</tr>
<tr>
<td>2. Test Scores Used to Match Groups</td>
<td>49</td>
</tr>
<tr>
<td>3. Comparison of Pretest Scores of the Two Student Groups on the TAAS Diagnostic Test</td>
<td>50</td>
</tr>
<tr>
<td>4. Variables in Hypotheses One Through Six</td>
<td>58</td>
</tr>
<tr>
<td>5. Comparison of Posttreatment Scores of the Two Student Groups on TAAS Mathematics Diagnostic Test, with Pretreatment Scores as a Covariant</td>
<td>60</td>
</tr>
<tr>
<td>6. Comparison of Posttreatment Scores of the Two Female Groups on TAAS Mathematics Diagnostic Test, with Pretreatment Scores as a Covariant</td>
<td>61</td>
</tr>
<tr>
<td>7. Comparison of Posttreatment Scores of the Two Low Achieving Groups on TAAS Mathematics Diagnostic Test, with Pretreatment Scores as a Covariant</td>
<td>62</td>
</tr>
<tr>
<td>8. Comparison of Posttreatment Scores of the Two Student Groups on Survey of School Attitudes, Mathematics, with Pretreatment Scores as a Covariant</td>
<td>63</td>
</tr>
<tr>
<td>9. Comparison of Posttreatment Scores of the Two Female Groups on Survey of School Attitudes, Mathematics, with Pretreatment Scores as a Covariant</td>
<td>64</td>
</tr>
</tbody>
</table>
10. Comparison of Posttreatment Scores of the Two Low
Achieving Groups on Survey of School Attitudes,
Mathematics, with Pretreatment Scores as a Covariant 65

11. Comparison of Posttreatment Scores of the Two
Student Groups on Fraction and Geometry Items,
with Pretreatment Scores as a Covariant 66

12. Comparison of Posttreatment Scores of the Two Low
Achieving Groups on Fractions and Geometry Items,
with Pretreatment Scores as a Covariant 67
CHAPTER 1

INTRODUCTION

Background and Significance of the Study

During the last few years, a new vision of mathematics education has emerged. This new vision of mathematics comes in response to numerous studies that show American children lagging behind their contemporaries in other industrialized countries (Stevenson, Lummis, Lee, & Stigler, 1990) and failing to master mathematical fundamentals at a level sufficient to sustain our current technology-based society (Dossey, Mullis, Lindquist, & Chambers, 1988). The call for reform in mathematics education has caused a reexamination of the kind of mathematics and mathematical thinking that people will require in an ever-changing, technology-dominated world. Willoughby (1990) summarizes the problem facing mathematics educators by stating, "People who will solve the problems of the present and future - or even understand and evaluate those problems and solutions - must have a far better grasp of mathematics than most people have at present, or have ever had in the past" (p. 4).

The old paradigm of mathematics instruction and learning accepts the notion that students have a limited understanding of the nature of math. A common perception still exists that mathematics is the one subject where the answers are either right or wrong with the teacher exercising sole authority. Unfortunately, too many students are comfortable with memorizing a set of rules, manipulating symbols and formulas, and mastering a collection of concepts, content to hear the "truth" delivered from the "expert" standing before them in
mathematics class. Yet Lockheed (Connolly, 1989) reports that students' adherence to this "copy theory" of learning "may be the most important deterrent to effective education" (p.74). Students who believe in this old notion of mathematics fail to see that understanding complex mathematics is essential; they are skeptical that an ordinary person could construct mathematical meaning for himself. However, the new vision of mathematics education, supported by researchers and professional organizations, recommends that mathematics be taught in such a way that people will be able to use mathematics to solve everyday, non-routine problems. Students should want to use mathematics, viewing it as a user-friendly tool, rather than a "nemesis to be avoided at all costs" (Willoughby, 1990, p.9).

Today, the notion of what mathematics is has also expanded greatly. Half a century ago mathematics for everyday life encompassed only simple arithmetic skills and rules, adequate for "shopkeeper" tasks. Now mathematics is considered to be a powerful language, "includ[ing] methods of investigation and reasoning, a means of communication, and notions of context" (NCTM, 1989, p.5). For this new conception of mathematics, the focus of mathematics instruction has shifted away from isolated computational skills and preparation for the next math course. New national mathematics instructional goals emphasize the use of mathematics in everyday life, focus on problem solving, promote reasoning skills, stress communication in the language of mathematics, and foster students' valuing of mathematics and their confidence in using math (NCTM, 1989). With modern technology so accessible, calculation and symbol manipulation can be done effectively and more efficiently by machines, but higher-order thinking skills and the ability to communicate intelligently about mathematical situations can be done only by people. Thus, new goals for
For mathematics educators, a key question is, "How do we effect these pervasive changes?" The literature reports that for children to succeed in their study of mathematics, students must be allowed to explore, examine, and express mathematical relationships they experience in everyday life rather than be required to memorize meaningless formal definitions or mimic procedures purely by rote (Cooney, 1990). Curcio suggests that a language experience approach may help students connect real-life mathematics to their experiences in school: "This personalized, reality-based approach encompasses such activities as listening, speaking, reading, and writing, where children are guided to express their reactions, ideas, and feelings regarding situations shared by the children in the classroom" (Cooney, 1990, p. 69). Several other researchers, as well as practitioners, have reported successes through similar uses of language experiences or communication in mathematics (Rowan, 1990; Wood, 1992; Burns, 1991; Vermont Department of Education, 1991). They report that communication in and about mathematics, especially through speaking and writing, enhances students' understanding of mathematics and empowers them as learners.

One aspect of communication, that of writing about mathematics, has received increasing attention from educators (Burns, 1992; Davison & Pearce, 1988b; Evans, 1984; Fennell & Ammon, 1985; Shaw, 1983). Professional journals have begun publishing numerous articles on writing in mathematics and many presentations have been made on this topic at national, state, and local
mathematics conventions and workshops, such as the NCTM annual conference and Texas' Conference for the Advancement of Mathematics Teaching (CAMT). Enlightened mathematics educators are finding that writing can be a valuable tool for facilitating students' mathematical development, from concept acquisition to problem solving abilities (Davison and Pearce, 1988b). These educators recognize that the new paradigm of mathematics supports a classroom in which students may also experience mathematics as a creative activity through written language. In fact, the literature has begun to give practical suggestions for how teachers might use several types of writing-to-learn mathematical tasks in their instruction. These writing tasks are generally categorized according to their purpose as either transactional or informative (as in writing procedures, definitions, justifications or summaries); expressive or reflective (as in expressing feelings or anxieties, thinking out loud, or reframing or clarifying in the writer's own words); or poetic or creative (as in designing word problems, writing just for fun, or creating stories, poems, or raps) (Britton, 1975; Davison & Pearce, 1988a; Evans, 1984; McGehe, 1991; McIntosh, 1991; Miller & England, 1989; Rose, 1989; and Wilde, 1991).

Nevertheless, in most mathematics classrooms, writing is a communication skill that has not been used to its potential (NCTM, 1989). Several studies of elementary and secondary mathematics classrooms reveal that writing is seldom used as an instructional technique (Davison and Pearce, 1988a). In many classrooms, the majority of student writing involves only copying, note taking, or filling in the blanks. When writing does occur in the mathematics classroom, it is "almost incidental instead of a planned activity to develop a deeper insight into mathematics." (Davison and Pearce, 1988a, p.493). A primary reason for the lack of planned writing in mathematics is that
mathematics textbooks historically have very few writing assignments that call for original written responses (longer than one or two sentences). Mathematics texts also lack instructional support or assistance for teachers on how to use writing in their classroom (Davison & Pearce, 1988a).

The hesitation many mathematics teachers have about using writing may also be attributable to their experiences with writing-across-the-curriculum programs that were introduced in the mid-1970's. These writing-across-the-curriculum programs promoted writing in all content areas to develop a better quality of writer. Producing better writers is not a focus of mathematics teachers. Their priority is better thinking and learning. When writing is used in an informal way to allow students to explore their mathematical understanding and gain ownership of knowledge, writing becomes an instructional tool. This informal kind of writing, called writing-to-learn, is a strategy for constructing meaning about content, for reflecting on ideas in order to acquire personal ownership of them, and for using natural language to make sense of new learning. Writing-to-learn is very different from writing-across-the-curriculum. "The goal of writing-across-the-curriculum was the improvement of the quality of students' writing, whereas the goal of writing to learn is the improvement of thinking and the facilitation of learning" (Gere, 1985, p. 5).

Need for the Study

The National Council of Teachers of Mathematics (NCTM) Curriculum and Evaluation Standards for School Mathematics includes "Learning to Communicate Mathematically" as one of its new standards, or goals, for students, recommending numerous opportunities for students to communicate in mathematics. While communicating mathematically, students are reflecting on
and clarifying their thinking about mathematical ideas and situations; relating their everyday language to mathematical language and symbols; and discovering that representing, discussing, reading, and writing about mathematics is an integral part of learning and using mathematics (NCTM, 1989). When teachers incorporate a variety of writing-to-learn tasks into their mathematics instruction, they are providing opportunities for students not only to meet the new goals of the NCTM, but also to reveal their thinking and reasoning.

Even though several research studies have been published that show positive effects on students' mathematical learning and attitudes when using writing-to-learn techniques, Birken (1989) and others suggests that more studies are needed. Birken acknowledges that many practitioners credit writing experiences for their students' improved mathematical performance, but she questions their (as well as her own) statistical evidence. She states, "More effort has to be put into formalizing our talk of success if we expect others to be willing to put time, resources, and effort into improving math classes through writing" (p.35). She calls for more grant proposals and research dollars to be focused on studies that will provide data to teachers who are skeptical of trying something new and to the administrators who are asked to encourage them. Fennel (1991) also calls for further study and clarification of writing in mathematics, specifically as it relates to problem solving and concept acquisition.

More teachers may express a willingness to try writing-to-learn in mathematics once they have more convincing evidence that improvement in their students' mathematical achievement and attitude will be forthcoming. However, just because these teachers seem receptive to the idea of writing in mathematics does not mean that they will implement it regularly. Those teachers who have experimented with writing assignments in mathematics report that ideas,
resources, and support for implementing writing-to-learn in mathematics are not readily available. These teachers either adapt writing ideas from articles or workshops, implement suggestions from other practitioners, or invent their own writing tasks. If staff development on how and when to use writing in the mathematics classroom were offered, good models and sources for planning and teaching writing activities were provided, and continued support were made available as teachers experimented with writing-to-learn tasks in mathematics, then perhaps more teachers, previously unconvinced or reluctant, would be willing to incorporate writing assignments into their mathematics instruction.

In this study, the researcher attempted to address teachers' hesitation to use writing as a tool in mathematics instruction by providing teachers with training, modeling, and support as they incorporated a writing-to-learn component into their mathematics instruction. Specifically, teachers were assisted in implementing writing-to-learn tasks as they taught fourth grade mathematics concepts. The three kinds of writing-to-learn tasks used in this study, as defined by James Britton (Britton, Burgess, Martin, McLeod, & Rosen, 1975), are classified according to purpose and are briefly described, as follows (see Chapter 2, Types of Writing and Use of Each in Mathematics, pp.33-46, for a more complete description):

1. **Expressive writing tasks**: Expressive writing tasks are of the reflective type and are used to help the writer explore or clarify his or her thoughts or feelings. The writing is personal, writer-oriented, and used for reflection. Informal in style, expressive writing is close to speech, often characterized by first person pronouns. Examples of these tasks include journal writing, diaries, first drafts, and letters to friends where the writer is revealing his or her own feelings or thought process.
2. **Transactional writing tasks:** Similar to expository writing, transactional writing tasks are informative types of writing in which the writer is primarily conveying information to other people. The writer is communicating to an audience using conventional prose to inform, persuade, or instruct. Transactional writing may be used to analyze problems, answer questions, produce verifiable evidence for given questions, or describe procedures, producing writing that is factual and subject matter centered. This type of writing also includes justifying a point by arguing from accepted premises or by generalizing from particulars. Examples of these tasks include summaries, descriptions of procedures, reports, term papers, and essays.

3. **Poetic writing tasks:** Poetic writing tasks are artistic expressions of the writer, not constrained by any particular rules of usage. This type of writing is intended to provide pleasure to both the sender and receiver. Frequently called creative writing, poetic writing is language used as art, highly imaginative and unconventional in style. Examples of these tasks are limericks, poems, songs, riddles, short stories, raps, videos, movies, skits, etc.

In assessing the effectiveness of the mathematical writing-to-learn tasks, answers to the following questions emerged:

1. Does the use of mathematical writing-to-learn tasks result in an increase in students' mathematics achievement?

2. Does the use of mathematical writing-to-learn tasks result in an increase in students' attitude toward mathematics?

3. Does the use of mathematical writing-to-learn tasks result in an increase in female students' mathematics achievement and/or attitude?

4. Does the use of mathematical writing-to-learn tasks result in an increase in low achieving students' mathematics achievement and/or attitude?
Overview of Research Design

The purpose of this study was to determine the effects of implementing writing-to-learn tasks in mathematics instruction on fourth grade students' achievement and attitude toward mathematics. Fourth grade mathematics teachers and students from two closely matched elementary schools in a large suburban school district in North Texas participated in the study. Teachers and students at one of the campuses served as the treatment group; teachers and students at the other campus served as the contrast group. The teachers in the treatment group were provided with staff development, modeling, and support in using writing-to-learn techniques in mathematics. In addition, the researcher assisted teachers in the treatment group with their lesson plan writing to ensure the inclusion of writing tasks in their mathematics instruction. Teachers in the treatment group involved their students in writing activities in mathematics for a ten-week period. Students in both the treatment and contrast groups were administered the Texas Assessment of Academic Skills (TAAS) Mathematics Diagnostic Test, a mathematics criterion-referenced test similar to the state mandated TAAS test, at the beginning and the end of the study. Students in both groups also completed the Survey of School Attitudes just before the treatment began and just after the treatment was completed. Student achievement and attitude measures were analyzed to test the hypotheses of the study.

Statement of the Problem

The problem of this study was to determine the effects of implementing writing-to-learn tasks in mathematics instruction on student achievement and attitude in fourth grade mathematics classes.
Hypotheses

1. The mean score on the fourth grade TAAS Mathematics Diagnostic Test for the group of fourth grade students who used writing-to-learn activities in mathematics will be significantly higher than the mean score of a contrast group of fourth grade students who did not use the same writing-to-learn tasks in mathematics.

2. The mean score on the fourth grade TAAS Mathematics Diagnostic Test for female fourth grade students who used writing-to-learn tasks in mathematics will be significantly higher than the mean score of female fourth grade students who did not use writing-to-learn tasks in mathematics.

3. The mean score on the fourth grade TAAS Mathematics Diagnostic Test for low achieving fourth grade students who used writing-to-learn tasks in mathematics will be higher than the mean score of low achieving fourth grade students who did not use writing-to-learn tasks in mathematics.

4. The mean score on a mathematics attitude scale, as measured by the Survey of School Attitudes, for a group of fourth grade students who used writing-to-learn tasks in mathematics will be significantly higher than the mean score of the contrast group of fourth grade students who did not use writing tasks in mathematics.

5. The mean score on a mathematics attitude scale, as measured by the Survey of School Attitudes, for a group of female fourth grade students who used writing-to-learn tasks in mathematics will be higher than the mean score of female fourth grade students who did not use writing-to-learn tasks in mathematics.

6. The mean score on a mathematics attitude scale, as measured by the Survey of School Attitudes, for a group of low achieving fourth grade students
who used writing-to-learn tasks in mathematics will be higher than the mean score of low achieving fourth grade students who do not use writing-to-learn tasks in mathematics.

**Definition of Terms**

**Texas Assessment of Academic Skills (TAAS) Mathematics Diagnostic Test**, as used in this study, refers to a criterion-referenced test compiled by the researcher from items published by the Texas Education Agency (TEA) in the TAAS specification booklet for fourth grade mathematics. The TAAS test is the state level criterion-referenced test administered to all fourth graders in Texas each spring. Because the TAAS test is secure, the researcher was not allowed access to the actual TAAS test items. However, the items published in the specification booklet were drawn from the same pool of items from which the actual TAAS test is drawn and have been determined by the TEA to be representative of the items that appear on the state level test. All of the items selected by the researcher were subjected to the same tests for validity and reliability as the actual TAAS items.

**Attitude toward mathematics**, as used in this study, refers to the extent to which a student has a positive or negative attitude about mathematics as measured by the Survey of School Attitudes Scale (Hogan, 1975).

**Low achieving students**, as defined in this study, are those students whose raw score on the TAAS Mathematics Diagnostic Pretest was below 35 or whose per cent of accuracy was below 67%.

**Writing-to-learn**, as used in this study, refers to the use of informal writing as a strategy for better learning and thinking. Writing is used in such a way that
students, using natural language, can explore, question, articulate, and refine their thoughts to impact learning.

Limitations

1. The study did not attempt to prohibit the teachers in the control group from using writing in their mathematics classes. All elementary teachers in the district have received base-line training on the benefits of using writing in all content areas. Because writing is a focus of this district, all elementary teachers in the district have been encouraged to provide students with opportunities to write about their learning in all subject areas.

2. Another limitation involves the amount of testing conducted during the time of year in which the study was conducted. Fourth grade students are tested in April with the standardized Norm-referenced Assessment Program for Texas (NAPT) and in May with the state-mandated TAAS test. While all fourth grade students in the district were administered the researcher's TAAS Mathematics Diagnostic Test as an assessment for diagnostic purposes, the fourth graders who participated in the study were required to take the same TAAS Mathematics Diagnostic Test again, at the end of the study as a posttest, as well as respond to a pretest and posttest on attitude toward mathematics. The extra testing and attendant tension may have affected the fourth graders' performance on the posttests for achievement and attitude.

3. A third limitation involves the assignment of all of one school's fourth grade mathematics teachers and their classes to the treatment group and all of the other school's fourth grade mathematics teachers and classes to the contrast group. Random assignment of teachers and their classes, irrespective of the school site, is most desirable, but was not possible for this study. Fourth grade
teachers at each school plan as a team. "Trained" and "coached" teachers might share information with the "non-trained" or "uncoached" teachers to the extent that non-trained teachers become as successful as the trained teachers in implementing the writing-to-learn tasks in mathematics instruction. While this sharing might be considered a benefit, it presents a problem for the analysis of data. To minimize this effect, all nontrained and uncoached teachers taught at a school other than the one where the training, coaching, and implementation of writing-to-learn tasks took place.
CHAPTER 2

REVIEW OF LITERATURE

This study is concerned with the effect of writing-to-learn tasks on students' achievement and attitude in mathematics. Therefore, the review of literature includes research on writing-to-learn, benefits of writing in the mathematics classroom, and types of writing and their use in mathematics instruction.

Writing-to-Learn

Writing-to-learn traces its roots to cognitive psychology. Several noted cognitive psychologists and learning theorists have provided crucial insights into writing and its teaching by giving explanations of how language (and, thus, writing) serves as a function of thinking. Their work illustrates that verbalizing is an essential component of thinking and that such verbalizing functions at several levels, from subvocal to finished writing.

In Thought and Language (1962) the Russian psychologist Lev Vygotsky describes the connections between thought, language, and writing. He states, "Thought is not merely expressed in words; it comes into existence through them" (p.125). The "inner speech" that one hears in his own head Vygotsky describes as the "mediator between thought and language, a dynamic, shifting, unstable thing, fluttering between word and thought. A thought is born through words. A word devoid of thought is a dead thing, and a thought unembodied in words remains a shadow" (p.149). Vygotsky further describes how writing becomes an extension of inner speech (talking to oneself) and, thus, demands a
"deliberate structuring of the web of meaning" in which the writer must engage in "deliberate semantics" to make connections and draw on relationships (Emig, 1983, p.127).

Jean Piaget, in his book *Six Psychological Studies*, presents a seminal interpretation of language as an activity of mind. In describing the stages of a child's cognitive growth, he credits the last stage of growth, the period of "formal operation," as the one in which the child develops an enhanced ability to deal with abstract language and complex verbal problems. During this stage, the child begins to distinguish the past and the future from the present, and differentiates the possible from the real. At this point, Piaget asserts that language is indispensable to the elaboration of thought. For Piaget, language serves two important functions: It allows development of increasingly complex thinking, and it promotes the child's ability to understand other perspectives about reality and separate them from his own (Foster, 1983). Piaget concludes that knowledge is highly organized, that learning involves the assimilation of new experiences into one's previous knowledge, and that intellectual development is not a passive incorporation of information but an active construction on the part of the learner.

Like Piaget, Jerome Bruner (Foster, 1983) also places language at the center of intellectual development. He describes language as "the instrument of thought" (p.10). He concludes that language satisfies the mind's need to categorize experiences and provides the means through which thought can deal with experience. Bruner agrees with Piaget that language provides the developing mind a method to deal with experience by abstracting from it and communicating about it. He believes language is crucial for learning.

Both Piaget and Bruner use a progression of stages to describe children's ability to deal with actuality. Children first learn concretely, or by doing, then
progress to representation with an image, and finally are able to symbolize or restate in words. Janet Emig of Rutgers, who has earned an international reputation studying the composing process of thousands of student writers, contends that all three of these levels of learning about reality are simultaneously employed when writing is used. First, "the hand which moves the pen across the page engages motor functioning" - the enactive level; next, "the eye that reads what is being written activates sensory functioning" - the iconic level; and, finally, "the mind which shapes and refines the message that is being written [requires] the deeper intellectual and analytical processes" - the symbolic level. (Bell & Bell, 1985, p.213). Emig (1983) concludes that "writing, through its inherently reinforcing cycle involving hand, eye, and brain, marks a uniquely powerful multi-representational mode of learning" (p.126).

Fulwiler (1982) also points out the uniqueness of writing. For him, writing "represents a unique mode of learning - not merely valuable, not merely special, but unique ... writing makes our thoughts visible and concrete and allows us to interact and modify them" (p.18). Writing can begin with one word, which brings to mind another word, and so on, eventually to form sentences, then paragraphs, which in turn suggest new words, sentences, and paragraphs. Emig compares this process of writing to an act of discovery which no other thinking process can develop as thoroughly. In fact, she claims that elaborated thinking is not really possible for most people without writing. While speech may be important for composing ideas, writing is much better. When one writes, he can manipulate compositions on paper, in addition to holding them in his head. Once written, compositions can be revised, refined, and rewritten because they are tangible and concrete. Emig states that most people cannot develop their ideas fully unless they make them visible by writing them down (Fulwiler, 1982). Emig
relates how Sartre abandoned writing once he was blind. He claimed that the inability to see his words rendered his thinking useless; he needed to visualize his thought in order to develop it (Emig, 1983).

Van Norstrand (1979) agrees with Emig that the nature of writing inevitably produces learning. He characterizes writing as *composing*—not grammar, not punctuation, and not spelling—and this composing becomes "a sustained activity of discovering and stating relationships among bits of information" (p. 178). These relationships evolve as one writes, by means of continually grouping pieces of information into clusters, and regrouping them with more information into new clusters. This regrouping and connecting of pieces of information result in the writer's evolving awareness of the implications of a subject about which he is writing. In effect, he learns about his subject as he writes. Beyer (1979) also credits writing with providing learners new insights into subjects. "When we conclude a written statement, we have usually discovered or generated something about our subject that we did not know at all or understand so clearly when we started" (p.176).

Draper (1982) promotes writing for providing opportunities to explore and question one's thinking, as well as to determine and display what one knows. Writing engages the imagination, intellect, and emotions and encourages expression of those attitudes, skills, and values necessary for effective learning in the disciplines. It is a unique learning activity that can preserve thoughts and data for future reference, analysis, and/or synthesis. Learning becomes personalized because each learner is able to respond at his own rate, to ask his own questions, and to form his own conclusions, theories, or generalizations. Emig (1983) also promotes the personal and self-paced nature of writing, as well as the opportunities for students to review as they write. Writing forces a
slowdown in thought processes, and this slowness seems to free some parts of
the brain, enabling it to explore ideas to make new discoveries and connections
(Gere, 1985). Britton advocates opportunities for students to write in every
curricular area because writing helps students get the subject material "right with
themselves" (Gere, 1985, p.2).

Different types of writing-to-learn programs in several curriculum areas
have been used in a number of research studies, many of which point to writing
as an effective method for internalizing content. Myers (1984) concludes that
students who participate in writing-to-learn programs are likely to learn more
content, understand it better, and retain it longer. In another study, Schubert's
(1987) comparison of classes with and without writing assignments confirm that
students who write-to-learn actually do learn and retain concepts better than
students who do not write as part of their course work.

One of the strongest statements of the need for using writing-to-learn
comes from Randall Freisinger (1982). His research makes a direct connection
between documented student inability to handle formal operations and schools'
lack of attention to the value of writing-to-learn. When students cannot function
at the level of formal operations, they may have difficulty with tasks requiring
higher order thinking, such as distinguishing relevant from irrelevant information,
determining cause and effect relationships, analyzing a line of reasoning, drawing
analogies, generating and/or evaluating inferences, visualizing outcomes,
searching for patterns, etc. Freisinger states that the "cognitive impairment of a
significant number of our students' is due to schools' neglect of the learning
function of writing" (Gere, 1985, p. 2).

Maimon (1989) maintains that for much of this century teachers of writing
ignored the vital connection between writing and thinking. Arthur Applebee
(1984) of Stanford University conducted a three and one-half year study of writing in all curricular areas in schools in the United States. His data revealed that writing activities most often involved calculations, short-answer responses, and fill-in-the-blank exercises. Almost all of the writing - from 87 percent to 99.5 percent in all subjects - was addressed to the teacher as an examiner; students rarely shared their writing with each other or served as the audience for their classmates' writing. Britton and his colleagues (1975) found similar results when they investigated the uses of writing in the different disciplines in British secondary schools. Another in-depth study, the Writing Across the Curriculum project in Scotland (Spencer, 1983), revealed that while some teachers believed writing to be an important skill needed for developing students' clarity and logic as thinkers, for self-expression, and for effective functioning in society, most of the teachers in this study, like those in Applebee's and Britton's, used writing primarily as a means of communicating information to the learner or for showing the teacher what the learner understands or is able to recall. These studies provided concrete evidence that writing was not being used extensively as a means of learning (Glatthorn, 1987a).

Fulwiler and Young (1990) report that the writing-across-the-curriculum programs that originated in the mid-1970's at American colleges and universities came in response to the perceived deficiency in student writing and thinking that studies such as those previously mentioned revealed. Also contributing to the movement to write in all the content areas was the interest in the 1969 publication of Janet Emig's pioneering study of the composing process. Numerous studies that built upon Emig's investigations followed, collecting data on the way writers of varying age and ability compose. The studies revealed that skilled writers work through a recursive process composed of several stages:
prewriting, drafting, revising and editing, and publishing (Glatthorn, 1987a). However, the studies also determined that unskilled writers tend to jump immediately to drafting without thinking and that as they write, they worry constantly about form and consider revision an unnecessary burden. Freisinger (1982) reports that as a consequence of Emig's work, many teachers began to give special attention to the writing process and began to develop strategies to nurture it. "This shift in consciousness from product to process is the single most significant change in composition pedagogy in the last decade" (p.6).

While many of the writing-across-the-curriculum programs attempted to improve both student writing and student learning, the focus was frequently directed toward improving the quality of writing. Writing-to-learn has different goals from writing-across-the curriculum. Writing-to-learn is not learning to write. The emphasis of writing-to-learn is on learning content, although writing skills are likely to improve through practice. Myers (1984) describes writing-to-learn as a process in which thinking - the organization, evaluation, and synthesis of knowledge - is essential. Teachers who use the writing-to-learn approach are encouraged to de-emphasize the importance of spelling, grammatical errors, and poor writing style; instead, they should be concerned with the quality of ideas expressed and the clarity with which they are expressed.

Several studies confirm that writing-to-learn employs a wide range of cognitive skills. Emig (1977) found that writing in a content area can cause students to analyze, compare facts, and synthesize relevant material. She cites Vygotsky and Bruner's contention that development of the higher cognitive functions, such as analysis and synthesis, is due to the use of verbal language - especially written language. Writing about a topic forces students to think about the topic, focusing upon and internalizing important concepts to somehow make
those concepts their own. Johnson's (1983) research corroborates Emig's: students who are required to write must do considerable thinking and organizing of their thoughts before they write - they crystallize in their minds the concepts studied. In their studies, Abel & Abel (1988) arrive at similar findings. Their research also has shown that writing requires students to think and organize their thoughts before they write. Young & Fulwiler (1986) proclaim the importance of writing because it generates understanding and communication. Beyer (1979) simply states, in the words of Vygotsky, that "writing is thinking" (p. 177).

Studies indicate that writing-to-learn can be used as a powerful tool to enhance learning in all subject areas. Sorenson (1991) found that when content area teachers incorporate writing in all areas of curriculum, students benefit in three ways: (1) they have a source for better understanding content; (2) they practice a technique which aids retention; and (3) they begin to write better. Langer and Applebee's (1987) report on the The National Study of Writing in the Secondary School showed that the more that content is manipulated through writing the more likely it is to be remembered and understood. The findings of Konopak, Martin, and Martin (1987), using a guided writing procedure, revealed that the writing group was better able to synthesize information and produce higher level ideas on the final writing task than a control group and a non-writing treatment group.

Writing-to-learn is not a formal approach. The teacher may choose from a wide range of strategies to implement this method, but all of them require a change in teacher behavior (Gere, 1985). Instead of being the source of knowledge, the teacher becomes a guide to help students find their own knowledge. Students become more actively involved when asked to write. When writing is used, every student is given an opportunity to discover, connect,
translate, and personalize knowledge. Most importantly, all students in the classroom are processing simultaneously. "Rather than listening to a few students' verbal answers, all students are engaged at once in writing. What more could a teacher want: individualized instruction on the group level" (Bemiller, 1987, p. 366).

The shift towards student-centered teaching demands a different kind of planning, classroom management, and expectations of the students. The student-centered classroom does not require the teacher to relinquish control, but instead demands that the teacher be even more responsible, providing leadership and guidance as students learn how to write-to-learn (Gere, 1985). Fulwiler (1982) best describes the classroom that infuses writing on a regular basis when he writes: "Writing changes the pace of the class; it shifts the learners into a participant role. Writing clears out a little space for students to interact with the ideas thrown at them and allows them to focus on problems while the stimulus is fresh" (p. 20).

Writing-to-Learn in Mathematics

The *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989) identifies learning to communicate mathematically as one of the most important goals of mathematics education. The *Standards* maintain that communication plays an important role in helping children construct links between their informal, intuitive notions and the abstract language and symbols of mathematics. In addition, communication also serves as a method for helping children make important connections among concrete, pictorial, graphic, symbolic, verbal, and mental representations of mathematical ideas.
According to Rowan, Mumme, and Shepard (1990), communication in and about mathematics serves several functions. Communication promotes (1) students' understanding of mathematics by allowing them to express their ideas, discuss with and listen to others, and clarify their own thinking; (2) shared understandings of mathematics through learners' discussions and exchanges about ideas and discoveries; (3) empowerment of students as learners because students' discourse, as well as methods of investigation, are valued; (4) a comfortable and secure learning environment with interaction among peers who willingly risk sharing their thinking; and (5) teachers' insight into their students' thinking since teachers will be listening more and talking less as students explain their reasoning and thinking.

Communication in mathematics requires students to listen, read, and write about mathematics, as well as interpret meanings and ideas. Writing and talking about their mathematical thinking clarifies students' ideas and gives the teacher valuable information from which to make instructional decisions (NCTM, 1989). However, in the past, students have been asked only to listen to and sometimes read about mathematics, rather than discuss or write about mathematics in their own words or phrases. Teachers and the textbooks routinely provided the verbal and written explanations (Venne, 1989). William Geeslin (1977), in his clinical studies conducted during the early 1970's concerning students' learning of mathematical structure, questions the traditional mathematics pedagogy of that era: "Have we emphasized getting the answer to the point where our students cannot talk or write about mathematical concepts?" (p.112). In his study, in which students in grades 4 through 12 were asked to write sentences or paragraphs about mathematical concepts, Geeslin concludes that writing about mathematics is useful both as a diagnostic tool for the teacher and as a learning
device for the student. By examining students' mathematical writing, Geeslin found that while students had nearly correct notions concerning the mathematics concepts, often many had important misconceptions about mathematics that had not been revealed by more traditional assessments. However, he cautions that students of all ages and abilities generally performed poorly on the various writing tasks, which he attributes to their lack of experience in writing about mathematics. He reports that many students were unable to express "a complete mathematical idea, much less a correct one...Primarily students have been asked only to 'get the answer' or 'prove the theorem'" (p.112). Geeslin suggests that with more practice the writing would improve.

The new paradigm of today's mathematics instruction, supported by research and endorsed by mathematics professionals and practitioners, promotes frequent use of students' communication, especially in written form. The NCTM Standards (1989) state that "Writing is a communication skill that has been used too infrequently in mathematics. It is particularly useful because it allows a child who is uncomfortable in oral situations to express understanding in a less public forum" (p.28). Geeslin (1977) prefers written tasks over verbal ones for several reasons: all students can participate simultaneously in a written task; students are required to be more precise when writing is required; teachers can spend more time assessing or responding to written products; teacher and student can review or edit the written work together; and students' technical writing skills improve. Abel and Abel (1988) also choose writing as their preferred mode of communication. They credit writing not only with enhancing students' ability to see new relationships and invent new ideas, but also with fostering success in a mathematics-related career. "Consider the need for clear and concise manuals to accompany computer hardware or software, or the need
to interpret and communicate the results of statistical analysis in understandable language" (p. 155). Mett (1987) also promotes the need for writing in mathematics when he reports that practicing scientists in research-and-development corporations spend over 30 percent of their time writing.

Teachers play a critical role in guiding students as they begin to write in mathematics, helping their students understand the purpose for writing, as well as how to go about getting started. The NCTM Standards suggest beginning writing with activities that ask for students to write letters to a friend about an activity they have done in math class or to keep journals for reflecting on their learning or expressing any confusion they might experience as they learn about new concepts. According to Strackbein and Tillman (1987) journal writing is one of the best beginning points for daily writing, functioning as a rough draft where one works out one's idea. Geeslin (1977) suggests that the first efforts at writing in mathematics be assessed on mathematical correctness; then, as students begin to write mathematically correct statements, the teacher may begin to assess clarity, precision, and completeness. Burns (1991) reads her students' initial written responses as first drafts, and almost always returns the papers for revisions. However, she consistently provides encouraging and very specific comments to each of her students about their writing so that they will know what to correct or elaborate upon as they rewrite.

Wason-Ellam (1987) also supports the gradual introduction of writing into mathematics instruction and believes that no student is too young to begin expressing their mathematical understandings in written form. Her study of first grade students' use of journal writing yielded very positive results. Over an eighteen week period, she asked her young students to record in their journals their impression of what they were learning in mathematics. As the children
became more comfortable with their recordings, they began to ask questions in their journals, order their experiences chronologically, connect new experiences with old, reflect on wrong answers, as well as correct ones, and venture guesses. Wason-Ellam concludes that the writing makes learning active and personal, and requires young children to do much more in mathematics than memorize, recall, or transcribe. Regardless of how teachers help students ease into writing-to-learn activities, Rowan, Mumme, and Shepard (1990) report that as students become used to the writing, they eventually grow to appreciate it as an important part of mathematics.

As teachers prepare for the introduction of writing-to-learn tasks in mathematics, they are cautioned to rethink their planning of activities to include time for developing these new writing skills, for modeling of their own thinking and resultant writing, for student sharing of their products, and for affirming the creative and divergent thinking that writing promotes. Fulwiler & Jones (1982) report that teachers spend much of their time preparing for classroom demonstrations or explaining information, but spend little time thinking about how writing can assist in both the learning and the assessment of the learning. The Bells (1985) suggest that writing in mathematics is important enough to become part of the daily routine of every mathematics classroom, with the writing tasks carefully designed to reinforce the mathematics concept or skill being taught. In the Bells' studies, "a basis premise is that the writing component of the math unit must be perceived as an integral element of the teaching process, not as merely an enrichment exercise" (p. 215). Fulwiler & Jones (1982) agree with this premise when they write:

Asking for the student's answer in writing should be an important pedagogical decision, not simply a trade-off in time.... Asking for a piece of writing involves students more profoundly in the learning
process; they must demonstrate not only 'knowledge' but also the ability to organize and explain that knowledge (p. 47).

Given that many students view mathematics as a stringent set of rules, facts, and procedures, writing activities can involve students in useful and enjoyable mathematical activities. Writing seems to free mathematics students of the idea that mathematics is a collection of right answers owned by the teacher - "a body of knowledge that she will dispense in chunks and that they will have to swallow and digest" (Zinsser, 1988, p.188). Both teachers and students report new enjoyment and lasting benefits of mathematics when writing is incorporated into instruction. LeGere's (1991) action research study called for a student-centered classroom in which she employed collaboration and writing in her mathematics instruction. She writes that students reported less anxiety and found the classroom environment less threatening. She notes that with her new techniques students consistently used higher-level skills as she required written analyses, not just answers. Wason-Ellam (1987), in her action research with first graders and journal writing in mathematics, reports that her students' continued reflection on information was ultimately more productive than simply listening passively, transcribing or reciting, as her students previously had done. In addition, LeGere (1991) claims that as the instructor, she developed a greater awareness of the relationship between what is asked of the students and how and what they will learn. She also states, "I experienced a freshness of attitude, a renewed commitment to teaching" (p.171). Her focus during class moved from finding the answer to processing and interpreting.

Using writing-to-learn techniques in mathematics does not cause course content to be altered or diminished. Instead, the writing-to-learn strategies are meant to be integrated into existing content to provide a way to deepen and
enhance the learning. While writing experiences do take more time than just lecturing, LeGere (1991) maintains that "lecturing plus these [writing] experiences takes little more time than repeated lecturing and enables the instructor to learn how the student has interpreted the lecture" (p. 170). Ganguli's (1989) study addressed this concern about time. In his investigation of the effectiveness of integrating writing in a developmental mathematics course, he found that adding writing instruction did reduce slightly the amount of time available for mathematics instruction, but student performance was better. Secondary teachers who participated in the action research study of Miller and England (1987) found that allowing students to write for five minutes for four times a week did not interfere with covering the prescribed curriculum for the year. In fact, they thought that in some ways the writing helped them to cover the material more effectively.

The NCTM Standards (1989) maintain that emphasizing communication in a mathematics classroom helps shift the classroom environment in which students are totally dependent on the teacher to one in which students assume more responsibility for validating their own thinking. LeGere's (1991) work in collaboration and writing in the mathematics classroom supports this standard. She advises that teachers "shed the 'Atlas complex,' the feeling that we must support the entire burden of responsibility for the learning on our shoulders, and instead share that responsibility with students in the classroom" (p. 166). She maintains that writing assignments should be designed to involve students in the learning process and give opportunities for critical thinking. Her work affirms Meyers' (1986) assertion that critical thinking skills develop best in an atmosphere of dialogue, interchange, and problem solving, not merely by listening to lectures. Carton (1990) reports similar findings in her study in which
students at several levels of mathematics worked cooperatively to create their own word problems. She concludes that, in addition to developing their own understanding of mathematical concepts, they "saw mathematics from the inside out, as creators rather than mimickers; they were 'doers' of mathematics, reflecting on and clarifying their own thinking about mathematical ideas in specific situations" (p.542).

Davison and Pearce (1988b) maintain that writing uses many of the thought processes that mathematics teachers would like to foster in their students, since performing a writing task requires students to reflect on, analyze, and synthesize the material being studied in a thoughtful and precise way. Flower and Hayes (1977) have examined the special relationship between writing and problem solving. They have studied the cognitive processes of experts and novices in a variety of professions as these people think aloud on tape while solving problems in mathematics, physics, chess playing, and composition of music. They conclude that the real challenge is "not just getting the ideas, but verbalizing them - get[ting] thinking down in words, phrases, sentences - fragments of writing. Until you can express what's in your mind in words, it can be said you don't really know it" (p.454). Thus, Geeslin (1987) suggests that students write step-by-step explanations of their problem solving to help students become more autonomous learners. Myers (1984) notes that the logic and organization that goes into good writing is similar to the processes involved in problem solving. "Sometimes the best way to master a mathematical concept is to put it into one's own words; sometimes the best way to solve a math problem is to paraphrase it to clarify relationships" (p.62).

Several other authors draw a parallel between the problem solving process used in mathematics and the writing process. Focusing on the writing
process - discovering a topic, deciding what one needs to say about it, organizing and structuring content, writing a draft, and then revising and editing the finished product - underscores a fundamental "problem solving" factor involved in writing that parallels the one which is found in the corresponding problem solving process - defining the problem, determining what information one already knows, devising a plan or a strategy for solving the problem, finding a solution, and verifying the results. The two procedures are strikingly similar and both require critical decision making on the part of the student (Bell & Bell, 1985). Flower and Hayes (1977) suggest that a problem solving approach works for many writers because writing as a problem-solving activity makes students self-conscious about the way they conceptualize. This self-consciousness leads to a more effective conceptualization and, thus, becomes a strategy for solving problems. Berkenkotter (1982) also contends that a writer is a problem solver of a special kind, since a writer's "solution" is dependent upon his framing of the problem, his goals, and his plans for achieving those goals. She suggests that applying traditional problem solving models to composing is helpful, especially during the early stages of writing which are often the most difficult for students. Both Flower and Hayes (1977) and Berkenkotter (1982) teach students to view each writing assignment as a problem to be solved and use certain heuristics (strategies) to solve those problems.

Rather than applying the problem solving process to writing, several authors report doing the reverse: they use the writing process to teach problem solving. Ford (1990) contends that using the writing process as a strategy for problem solvers helps learners focus on the question being asked, look for essential information, and become familiar with the structure of the written problem. In addition, students must be given the opportunity to write their own
word problems using the writing process on a regular basis and must be allowed time to work on problems that others have written. Fennell and Ammon (1985) implement a similar kind of strategy to connect the concepts of problem solving and writing. They teach problem solving strategies through children's writing of their own word problems. They credit this approach to writing experts, such as Donald Graves, who wrote that "until [students] work on the other side at the point of formulating word examples, they will not fully understand the reading contained in mathematics" (p.24). Fennell and Ammon use Graves' four step writing process - prewriting, writing, rewriting and revising, and publication or sharing to help elementary children write their own problems to solve. They report that students increased their progress in writing and mathematics while integrating reading, critical thinking, and the collection and organization of data.

Benefits in the affective domain can be a result of writing-to-learn in mathematics for students and teachers. As a side benefit of his project in which they used the writing process as a method for instructing problem solving, Fennell and Ammon (1985) report that students' confidence in and enjoyment of mathematics were boosted. McGehee (1991) also credits her seventh grade students' problem-writing project with more than mere engagement of students in writing and learning. She reports an improvement in her students' self esteem after involving them in the writing activities. She attributes the positive changes to the pride her students displayed in their quality of work and the ownership they felt for the work they created. Several other researchers and practitioners have used journals (Fennell & Ammon, 1985; Nahrang & Peterson, 1986) and mathematics logs (Shaw, 1983) to help students express their anxieties about mathematics and the problems they encounter in the learning of mathematics. Many students express relief when allowed this outlet. Teachers also report an
improvement in their own attitudes toward students and a new enjoyment of the mathematics content after experimenting with writing (Miller & England, 1989). Teachers claim they obtain powerful insights into students' error patterns and misconceptions when students write in mathematics (Miller & England, 1989; Geeslin, 1977). Consequently, teachers were able to reteach immediately, rather than after a test.

Formal studies, as well as informal studies, have yielded positive results at all levels when the writing-to-learn theory is incorporated into mathematics instruction. Marilyn Burns (1988) reports that by writing what they think, students at any grade level will develop more fully their mathematical reasoning and understanding. Evans (1984) relates improved mathematics scores when writing was incorporated into fifth graders' instruction on geometry and multiplication. In her action research, she concludes that through writing, her students came to "own" the mathematical knowledge, rather just "rent" it as they had in years past. Ganguli's (1989) classroom study found that student performance in a college developmental mathematics program increased when writing was integrated, even though the amount of time for instruction was somewhat decreased. In a high school geometry writing project, Linn (1987) reports that students gained insights into their own learning style. She states that when students were writing, they were forced to synthesize information. Thus, they became aware of what they did and did not know and, ultimately, discovered their own strengths and weaknesses in learning. Bell and Bell (1985), in their study with ninth graders, report similar findings. Students who completed writing assignments on mathematics problems became better problem solvers than students who did not. The Bells conclude that when students explain themselves clearly, students become more conscious of their thinking processes as they perform the
computation and analysis involved in solving mathematics problems. In another study, Mett (1987) attributes improved student study habits, as well as long-term retention, to students' writing activities in calculus. In addition, students expressed more enthusiasm for mathematics and writing, indicated a positive response to the writing activities as a means of communication with the teacher, and utilized the writing as a personal learning tool.

When using writing-to-learn in mathematics, teachers learn to be explicit and to provide examples using everyday language in mathematical contexts. Connolly (1989) suggests that ordinary language, through the use of writing, promotes Dewey's call for emphasis on cultivating experience as the motivating factor behind learning in schools. Using ordinary language to write about mathematics dispels the notion that a mathematician is a special breed or a member of an elite group who knows and speaks a secret language. Rose (1989) suggests that a greater use of writing may also enable teachers, especially elementary, who have more limited backgrounds in mathematics to teach mathematics more effectively and less anxiously. By making mathematics accessible for all through writing in mathematics, teachers may better reach sectors of the student population that have not previously thought mathematics to be accessible. The use of ordinary language may help break cultural barriers that have traditionally prevented minorities and women from achieving well in mathematics.

Types of Writing and The Use of Each in Mathematics Instruction

Writing can be classified according to the function it serves or its purpose or aim. Several different classifications of writing are described here and parallels are drawn among them. All of the classifications provide for a variety of
functions and audiences to be served. The use and benefits of each type of writing are described, along with recommendations for their use in mathematics instruction. Regardless of which classification is adopted, all encourage development of writing tasks which require students to write in different modes and for different audiences. The author of this study has chosen to use Britton's classification of writing when designing writing-to-learn tasks used in this study.

James Britton and his colleagues (Britton, Martin, McLeod, & Rosen, 1975) use the three function categories of transactional, expressive, and poetic to classify writing. These categories were formed as a result of a study conducted to investigate the relationship between writing and learning. The research team examined over 2,000 pieces of writing collected from British school children between the ages of eleven and eighteen and then classified each piece according to the function it served. The research team defines transactional writing as the "language to get things done - to inform, persuade, or instruct an audience in clear, conventional concise prose" (p. 160). In transactional writing, the writer is primarily interested in conveying information. It is the language of newspapers, technical reports, and essays. Expository writing of all kinds falls into this category. In their research studies, Britton's team found that most writing performed in school (63%) was transactional: term papers, laboratory reports, essay exams, and the like. Fulwiler (1982) notes that this most common category of school writing is also the most commonly demanded in the world of work: letters, memos, and proposals. "It is important, therefore, that students learn to do it well - clearly, correctly, concisely, coherently, and carefully" (p. 45). Examples of transactional writing in mathematics classes include step-by-step descriptions of mathematical procedures, justifications of conclusions drawn,
comparisons of similar or contrasting problems, and explanations of mathematical concepts or ideas.

The second classification of writing, according to Britton (1975) and his team, is expressive. This kind of writing might be called "thinking aloud on paper" - a means of exploring one's thoughts. Britton describes expressive writing as "self-expressive or close to the self ... it reveals the speaker, verbalizing his consciousness" (p.90). The primary function of this expressive writing is not to communicate, but to order and construct meaning for one's own understanding. Expressive language becomes a tool for discovering, for shaping meaning, and for reaching understanding. While Britton's other two forms of writing are not characterized by any particular audience, the audience for expressive writing is defined as a close group with shared expectations. Thus, while expressive writing is intended for the writer's own use, it might be understood by a reader who has shared much of the writer's earlier thinking, but it could not be understood by one who was not familiar with the context. This kind of writing looks like speech written down and usually contains first person pronouns, is unstructured and informal in style, and may contain colloquialisms. Expressive writing is the kind found in personal journals - it can be "tentative, talky, speculative, exploratory, digressive, and searching" (Bemiller, 1987, p.362). Examples of expressive writing in mathematics classes include journal writing in which students express opinions, feelings, or frustrations, and journal dialogues in which students can ask questions of the reader (usually the teacher) or make conjectures that require a response from the reader.

The third type of writing, according to Britton and his research team, is poetic writing. "Poetic writing uses language as an art medium. A piece of poetic writing is a verbal construct, an 'object' made out of language" (Britton, Martin,
McLeod, & Rosen, 1975, p.91). Poetic writing is language used "to recount or recreate real or imagined experience for no other reason than to enjoy it ... it becomes an immediate end in itself, and not a means " (p. 91). Unlike transactional writing, poetic writing cannot be understood in separate bits, because its meaning depends upon its formal unity. Readers also do not expect poetic writing to be true in the same sense as transactional writing. Poetic writing is frequently called creative writing and can be highly imaginative and unstructured. While poetic writing may be poetry, it does not have to be; drama, song, and fiction fall into this category, as well. Examples of poetic writing in mathematics classes include math raps, poems, songs, mathematics stories, skits, and original problem writing.

Like Britton's study, the National Study of Writing in the Secondary School, conducted from 1980-1982, also examined thousands of pieces of writing and classified them into three main categories according to function: informational, personal, and imaginative. This study was conducted in order to understand more completely the role that writing plays in academic learning and to find ways that writing can be used more effectively in high school classrooms. The resulting categories of this study strongly parallel those of Britton's study. The first type of writing, informational, is akin to Britton's transactional writing, in that it uses language to convey information, advise, instruct, or persuade. Informational writing also can be used to record facts, explain ideas, exchange opinions, and transact business. The second type, personal writing, is like Britton's expressive writing, as it is "close to the self," unstructured writing, used to explore new topics or share ideas with a close friend. In personal writing the author attempts to record and explore his feelings, mood, or opinions. It is the "thinking aloud" type of writing. The last type, imaginative writing, is very similar to Britton's third type -
poetic writing - and uses language as a medium to make a construct, an arrangement, or a pattern. Personal narratives, poems, or play scripts fall into this category. As with Britton's study, the researchers of this national study concluded that different kinds of writing activities lead students to focus on different kinds of information and to think about information in different ways (Applebee, 1984; Langer & Applebee, 1987).

Another classification of writing is provided by the noted rhetorician James Kinneavy (1971). For Kinneavy, "aim" is the crucial determinant of discourse. "Purpose in discourse is all important. The aim of a discourse determines everything else in the process of discourse" (p. 49). Kinneavy defines "aim in discourse" as that "aim which is embodied in the text itself - given the qualifications of situation and culture" (p.49). According to Foster (1983), "Kinneavy's purpose is to categorize all aspects of 'an oral or written situation,' using the 'communications triangle' that breaks down into 'encoder,' 'decoder,' 'signal,' and 'reality' " (p.48). Kinneavy's resultant classification of writing according to aim yields four categories: referential, persuasive, literary, and expressive. The referential category of discourse is subdivided into informative, scientific, and exploratory discourse. In addition, Kinneavy also separates purpose from its structure or form (description, narration, classification, evaluation). "Britton's transactional writing shares some of the features of Kinneavy's referential and persuasive writing, Britton's poetic function is very similar to Kinneavy's literary aim, and their joint use of the expressive category reveals similar purposes" (Foster, 1983).

For writing-to-learn purposes, a rigid classification system of the type of writing is not of crucial importance. What is important is for students to have opportunities to engage in a variety of writing tasks, especially those that are of
the "expressive" or "personal" types, for these allow students to write about their feelings and reactions toward mathematics learning. Since most of the writing in mathematics has traditionally been of the informative, transactional, or referential type, in which mathematics students have been asked to write short answers or simple explanations to the teacher for grading purposes, practitioners must be encouraged to provide alternative kinds of writing tasks, especially those that encourage reflection and exploration.

While students do learn and process information in performing these [transactional writing] assignments, none of these promotes writing primarily for the sake of the learner, and none of them encourages students to make school knowledge personally their own. The demand for impersonal, unexpressive writing can actively inhibit learning because it isolates what is to be learned from the vital learning process - that of making links between what is already known and the new information (Fulwiler, 1982, p.22).

Britton's research confirmed that expressive writing was the least frequent kind of writing assigned in school (only 5.5%), yet he recommends that expressive writing become a major part of young children's' experiences (Foster, 1983). Freisinger's (1982) research included similar findings. He found that the farther along in school children progress, the less expressive writing they are asked to perform. Students are asked to do more transactional writing, but most of these assignments require students to inform rather than to speculate or persuade. In fact, Freisinger states that "the excessive reliance on the transactional function of language may be substantially responsible for our students' inability to think critically and independently... Product-oriented, transactional language promotes closure" (p.9). Emig (Freisinger, 1982), in her research with high school students, also found a predominance of transactional writing. Emig contends that the reliance on this one type of writing reflects the educational system's neglect of the discovery function of language.
Britton stresses the relationship that exists between the expressive, transactional, and poetic writing. He claims that success with transactional and poetic writing comes from involvement with expressive writing. He states: "Transactional or poetic writing processes should begin in an expressive phase, then move either toward full, explicit communication for an audience outside the writer's context [transactional] or toward perfection of a verbal object [poetic]" (Freisinger, 1982, p.8). Britton's coresearcher Nancy Martin further explains: "The expressive is basic. Expressive speech is how we communicate with each other most of the time, and expressive writing, being the form of writing nearest speech, is crucial for trying out and coming to terms with new ideas" (Fulwiler, 1982, p. 20).

Mathematics researchers and practitioners endorse expressive writing and claim it can be a powerful tool for helping students construct their own learning. Wason-Ellam (1987) suggests that expressive writing makes learning active and personal, and does not relegate students to learning only by memorizing, transcribing, and recalling. Students who learn actively by writing acquire ownership of the information. Thus, reflecting on information is more effective than transcribing and reciting. For example, an expressive writing prompt which calls for reflection is as follows: "How is the pie graph that the class built today different from the bar graph we built yesterday? Give another example of a situation in which you would use a pie graph instead of a bar graph." Other expressive prompts may be more analytical, such as: "Remember when you learned how to make a pie graph? Imagine that you are writing a note to your best friend to explain how to do this. Write your note, assuming your friend really wants to know how to make this kind of graph and must rely only on you for the explanation."
The literature reports numerous instances of mathematics teachers assigning writing tasks of the expressive type to be kept in math journals. As defined by Nahrgang and Peterson (1986), the journal is a diary-like series of writing assignments, with each entry being a short written response to the teacher’s question, statement, or set of instructions. All responses are usually written in prose rather than in the traditional mathematical style of numbers and equations. The students use an expressive writing style so that their responses are spontaneous and all their thoughts are recorded. Nahrgang and Petersen give two important reasons for assigning expressive writing tasks in math journals: first, this kind of writing allows students to proceed at their own rate and to construct understanding of mathematical concepts using their own experiences; and second, expressive journal writing provides teachers a unique diagnostic tool since the writings of students immediately reveal areas of confusion and expose misunderstandings of mathematical concepts.

Writing with journals provides a vehicle for open communication between teacher and student. Abel (1988) reports that when teachers assign expressive journal writing, students have a chance to explore their feelings and new ideas, and the teacher obtains insights into students’ feelings and understandings of the mathematics being learned. By asking students to talk or write about their thinking, teachers are telling students that they value what the students have to say. Teachers’ responses to their students’ journals are vital to the success of journal writing. Gordon and McInnis (1993) report that “a driving force for the students’ writing appears to be their keen interest in the teacher’s response and the need to maintain that communicative bond” (p. 39). In their study, students reported they felt lines of communication were open between them and their teachers, and at times their journal writing served as a therapeutic tool. For
many students who are non-talkers, talking on paper also proves to be easier than talking directly to the teacher (Gordon & McInnis, 1993). McIntosh (1991) notes that while teachers do not need to collect journals every day, at least once a week teachers should read what their students have written and respond in writing to something in each student's journal. Even a brief response conveys that what the student has written is important and that the teacher is interested in knowing more, including what he or she might do as a teacher to help. Teacher's responses to journal writing need to be regular and sincere, but not judgmental or evaluative. Responses may be in the form of comments, questions, notes of encouragement, and/or assurance, all of which show that the teacher is "listening" and cares. "In essence, the journal is the private interview or the hotline between a student and teacher" (Gordon & McInnis, 1993, p.42).

Azzolino (1990) advises teachers to be flexible as they begin to assign expressive writing in journals since writing as a teaching tool is a very personal thing. Some writing assignments work better than others in eliciting reflective comments from students; teachers need to experiment with different kinds of prompts. For example, Miller and England (1989), in their study of journal writing with algebra students, found that the simpler and more direct the writing prompts were, the better. They found that more complex prompts with more questions or details only frustrated students, especially those who were struggling. Hence, longer, more elaborate assignments yielded less writing, even though the intent was to generate more. In addition, since writing tasks are not the end but the means for mathematics learning, errors in spelling, grammar, or punctuation should not be dwelt upon.

Once expressive journal writing has become routine in mathematics class, both teachers and students frequently report benefits to the affective domain, as
well as the cognitive. Bemiller (1987) writes: "I encourage these [expressive writings] because I believe that the effectiveness of learning depends upon one's entire psychological, physiological, emotional, and social being. Personal writing often clears the mind and emotions of barriers to learning" (p. 364). Another teacher writes about his satisfaction with journal writing in mathematics:

Writing in math class is not a panacea. Still, by learning and writing about related topics, by writing about problems which puzzle them, by writing about their fears and feelings, students begin to see math in more human terms. For me it is a way to get to know more about those varied and wonderful people who are my students (McIntosh, 1991, p.432).

Miller and England (1989) contend that students' comments about writing indicated that they enjoyed the opportunity to express themselves. "The students suggested that, because of the writing, the teacher expressed concern about the problems they were having and viewed the writings as a means through which the teacher could find out how to help them" (p.310). One fifth grade student writes: "I feel more confident in math. I'm not afraid to give a wrong answer now... It feels like your [sic] a friend trying to teach - not a teacher trying to be freindly [sic]. Thanks!" (Gordon & McInnis, 1993, p.41).

By allowing students an opportunity to present what they think is important, teachers are in effect giving students greater power and control over their own learning. Gordon and MacInnis (1993) describe this empowering effect on both students and teachers when expressive journal writing is used:

Students chronicled their frustrations and their confusions as they reflected on their learning in mathematics. They saw the journal as a place to take risks, to make mistakes, to sort out and to be open about problems they had in understanding mathematics. They also became aware of what they know and what they did not know. As a result, they could then begin to exercise some control over their own learning. Thus, writing in the journal empowered them in still another way. At the same time, they informed us [the teachers] of their difficulties in their development as mathematical thinkers (p. 41).
In addition to expressive journal writing, the literature also supports the use of poetic or creative kinds of writing assignments to increase learning. Art Young (1982) writes:

Creative writing is one important way to wake in a student a pleasure in the very language, a sense of exploring his own activity... We are familiar with testimonials from many sources which acknowledge that the creative impulse is central to the development, understanding, and application of knowledge. Reasoning by analogy and communication by metaphor are generally recognized as integral strategies of successful thinkers and writers in every discipline (p. 79).

Britton believes that poetic writing, like transactional and expressive writing, enables students to better understand course material they are studying. He states that poetic writing about the subject matter of the class is a unique kind of composing which requires a different outlook toward language, experience, audience, and subject matter. It involves different emotions and cognitive operations and provides the freedom important to making imaginative connections (Young, 1982).

Several authors report the use of successful creative writing by asking students to create their own word problems. Wilde (1991) states that students create word problems quite different from those found in textbooks. She found the most fruitful opportunities to create word problems were those based on experiences meaningful to the students. Kliman and Richards (1992) concur. In their classroom-based research, they asked students to write their own mathematics stories - stories about a familiar situation involving a problem that can be resolved with the aid of mathematics. They report:

As students share and discuss their stories with the class, they bring their everyday perspectives, experiences, and problem-solving skills to bear on the solution process. They learn to value and build on the problem-solving skills they develop outside of school, they develop confidence in their mathematical abilities, and
they come to see mathematics as meaningful and relevant to their everyday lives (p.138-39).

Kliman and Richards (1992) encourage students to use qualitative and quantitative information in the solution process. They recommend giving students opportunities to consider their own values and preferences, as well as the results of their calculation, when solving problems. Britton supports their recommendation:

As stories children write become 'shaped stories,' more art-like, they move from Expressive towards the Poetic. The more 'shaped' they become, the more effectively they enable writers to explore and express their values, those ways of feeling and believing about the world that make us the sorts of people we are (Young, 1982, p. 86).

Bland and Koppel (1988) report that when students are asked to write about their learning, students "yearn for opportunities to express their thoughts in creative ways" (p.60). Students can be asked to compose a multiplication rap in which all the multiplication facts for a certain number are put into rhyme; they can be encouraged to write a story in which some of the words are replaced with mathematical symbols; or they can be instructed to design a board game that uses the mathematics concepts being studied. Miller and England (1989) suggest giving students writing assignments that are "just for fun." For example, students might be asked to respond to the questions, "What is your favorite single digit number? How many reasons can you list for your choice? What about its shape do you like? What do you think about when you see the number? What does it remind you of?"

McIntosh (1991) suggests that poetic or creative writing assignments may appeal to students who have a difficult time in mathematics, but who excel in the language arts areas. She argues that appealing to their areas of strength in mathematics class may help them feel more positive about mathematics, as well
as enhance their learning. She reports that encouraging students to write poems about mathematical concepts, letters to mathematicians of yore, or skits involving mathematical concepts (geometric shapes, numeration properties, etc.) can produce a quality of writing that may pleasantly surprise or even overwhelm teachers.

Much of the current literature on writing-to-learn in mathematics focuses on expressive and creative writing prompts, most likely because these kinds of writing have not traditionally been assigned in mathematics classrooms until recently. However, there are still many benefits in assigning transactional or informational writing prompts in mathematics. Miller and England (1989) use teacher-focused instructional prompts as a type of transactional writing to elicit thinking and writing about a specific topic. For example, students might be given a prompt such as, "Tell me what the main point of today's lesson was" or, "Explain to me why your solution to the problem is reasonable." While these prompts call for reflection on the part of the student, there is less room for expressing feelings, opinions, or creativity. McGehe (1991) uses a guided-response strategy to help students analyze their thought processes as they solve problems or perform computations. For example, students might be asked to respond in writing to the steps required in adding two whole numbers with regrouping using base-ten blocks. Another example might require students to use a four step problem-solving plan (Step 1: Understand the problem; Step 2: Devise a plan; Step 3: Carry out the plan; Step 4: Look back) and explain in writing how they went through each step of the process to arrive at their solution. Using this method, the teacher focuses students' thinking in a particular direction but still allows for some creativity and reflection. Azzolino (1990) uses sentence completion, rewording, debriefing, and word banks as methods to focus students'
thinking through transactional writing. In sentence completion, students finish the sentences that the teacher has begun. For example: Lines and segments are similar because ___________. Lines and segments are different because ___________.

Rewording requires students to take a statement, definition, or procedure and reword or rewrite it in their own words. Rewording is an excellent diagnostic technique that requires students to demonstrate understanding. Debriefing is a form of summarization used as a technique for closure, requiring students to list the most important concepts, steps in a procedure, or new vocabulary discussed. Word banks are lists of words with which students write a sentence or paragraph using several or all of the words in the bank. Both debriefing and word banks are kinds of writing that help students organize and personalize new information.

Writing-to-learn in mathematics - whether expressive, transactional, or poetic - requires the student to engage his or her thinking processes and mentally to manipulate ideas, concepts, opinions and feelings. "Different kinds of writing activities lead students to focus on different kinds of information, to think about that information in different ways, and to take quantitatively and qualitatively different kinds of knowledge away from their writing experiences" (Langer & Applebee, 1987, p.46).
CHAPTER 3

METHODOLOGY

Selection of the Population

The school district in which the research was conducted had a total student population of approximately 33,000 students with 26 elementary campuses at the time of the study. Fourth grade mathematics teachers and students from two closely matched elementary campuses participated.

The treatment group consisted of the fourth grade mathematics teachers at one elementary campus and 125 fourth grade students, 63 of whom were female and 62 were male. Forty-five of these students were classified as low achieving, as defined by the TAAS Mathematics Diagnostic Test.

The contrast group consisted of the fourth grade mathematics teachers at another elementary campus and 118 fourth grade students, 59 of whom were female and 59 were male. Thirty-seven of these students were classified as low achieving, as defined by the TAAS Mathematics Diagnostic Test.

The treatment group and the contrast group were kept at separate campuses because of the mathematics teachers' commitment to team planning. At both schools, the fourth grade mathematics teachers plan weekly for all of their mathematics instruction. Random assignment of classes to a treatment or contrast group would require the mathematics teachers at each campus to abandon their team planning and plan alone or else risk contamination of the study through the sharing of their teaching ideas and activities that involve writing, especially if the writing activities are successful.
Campuses were matched according to demographic criteria collected by both the district and the Academic Excellence Indicator System (AEIS) Report, published by the Texas Education Agency (TEA); the fourth graders' previous year's mathematics achievement scores, as measured by the Texas Assessment of Academic Skills (TAAS); and intellectual abilities, as measured by the range of mean scores for the past three years on both the quantitative and verbal sections of the fourth grade Cognitive Abilities Test (CogAT).

Demographic data collected by the Academic Excellence Indicator System (AEIS) and the district are reported in Table 1.

Table 1
District and Academic Excellence Indicator System Demographic Data Used to Match Groups

<table>
<thead>
<tr>
<th>Demographic Data</th>
<th>Treatment</th>
<th>Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>% Economically disadvantaged</td>
<td>6.6</td>
<td>7.2</td>
</tr>
<tr>
<td>% Total Ethnic minority</td>
<td>16.9</td>
<td>19.2</td>
</tr>
<tr>
<td>% African-American</td>
<td>6.5</td>
<td>7.0</td>
</tr>
<tr>
<td>% Hispanic</td>
<td>5.2</td>
<td>3.2</td>
</tr>
<tr>
<td>% Asian</td>
<td>5.2</td>
<td>9.0</td>
</tr>
<tr>
<td>% Limited English Proficient</td>
<td>1.3</td>
<td>3.0</td>
</tr>
<tr>
<td>% Mobility</td>
<td>24.0</td>
<td>30.0</td>
</tr>
</tbody>
</table>

The AEIS uses demographic data to formulate a ranking of schools specifically for the purpose of academic comparison. The AEIS reports the following demographic factors: percent of students who are economically disadvantaged,
percent of students in minority groups, percent of limited English proficient students, and percent of student mobility. Economically disadvantaged students are defined as those who are eligible for free or reduced-price lunch or eligible for other public assistance. The mobility factor is calculated as the sum of students taking the TAAS who were reported as enrolled in the district or any district in Texas for two years or less. While the AEIS combines all ethnic minorities into one category, the district disaggregates this data and reports separately the percent of African-American, Hispanic, and Asian students at each grade level.

Schools were also matched on the basis of mathematics achievement and aptitude, as reported below in Table 2. Fourth grade students' total mathematics mean raw scores on the third grade TAAS, administered to them in 1991 when they were third graders, were used to compare achievement. Cognitive Abilities Test (CogAT) scores from the last three years' classes of fourth graders (1990-1992) were used to compare ranges of both quantitative and verbal aptitudes.

Table 2

Test Scores Used to Match Groups

<table>
<thead>
<tr>
<th>Tests</th>
<th>Treatment</th>
<th>Contrast</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991 Third Grade TAAS Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mathematics (mean score)</td>
<td>1764</td>
<td>1771</td>
</tr>
<tr>
<td>Fourth Grade Quantitative CogAT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(mean range for 1990 -1992)</td>
<td>112.6 - 115.4</td>
<td>111.8 - 115.4</td>
</tr>
<tr>
<td>Fourth Grade Verbal CogAT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(mean range for 1990 -1992)</td>
<td>107.8 - 110.2</td>
<td>107.9 - 111.9</td>
</tr>
</tbody>
</table>
As can be seen from Table 2, the fourth graders' mean raw scores on the third grade TAAS mathematics section were extremely close. In addition, from 1990 to 1992, the mean quantitative and verbal CogAT scores for fourth graders at both schools have been relatively consistent, with less than a four point range.

One final test was used to match the two campuses: an analysis of variance was performed on the achievement pretest scores, as measured by the TAAS Diagnostic Test, to determine if any significant difference between the two groups existed before the treatment began. As can be seen from Table 3, the analysis revealed a $p$-value of 0.1655, which exceeds the 5% level of significance. It can therefore be concluded that there was no significant difference in pretest scores for the two groups.

Table 3

**Comparison of Pretest Scores of the Two Student Groups on the TAAS Diagnostic Test**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>F-Ratio</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>125</td>
<td>36.376</td>
<td>6.8507</td>
<td>1.9346</td>
<td>.1655</td>
</tr>
<tr>
<td>Control</td>
<td>118</td>
<td>37.653</td>
<td>7.4986</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In addition to the data above, interviews were conducted with the district's coordinator of testing to confirm the selection of the two schools. The testing coordinator reported that the two campuses were frequently matched for data comparisons. For instance these two campuses have been matched when the principals of the schools sought to compare TAAS scores, NAPT scores, special education enrollments, attendance, etc.
Principals at both campuses reported interest in the study, since the district has established process writing as a district priority. While the purpose of this study is not necessarily to instruct students in the writing process, research studies have indicated that a by-product of writing-to-learn programs has been an improvement in students' writing skills. Both principals have made writing a focus of their instructional program for the past three years, and were, thus, willing to participate in a study that might produce an increase in achievement or attitude due to writing activities.

Visits with teachers in the treatment group to present the purpose of the study confirmed their interest in promoting writing activities, as well as their concern for improving their students' mathematics achievement and attitude. They indicated a willingness to learn more about writing-to-learn techniques and agreed to meet frequently with the researcher to design mathematics lessons using writing tasks.

Instrumentation

Two instruments were used to collect data on mathematics achievement and attitude toward mathematics to test the hypotheses of this study: the Texas Assessment of Academic Skills (TAAS) Mathematics Diagnostic Test, a mathematics criterion referenced test similar to the state mandated TAAS, and the Survey of School Attitudes. The data from these two assessments were used in comparing the performance and attitude of the students taught by the trained teachers who used writing-to-learn tasks with that of the students taught by the non trained teachers who did not incorporate multiple writing tasks into their mathematics instruction.
To test mathematics achievement, the researcher assembled a pretest/posttest mathematics criterion-referenced test, the TAAS Mathematics Diagnostic Test (see Appendix A), from test items provided by the Texas Education Agency in the specification booklet for the fourth grade mathematics TAAS. The items in the specifications booklet, and, thus, on the researchers' instrument, were selected from a pool of test items from which the items on the fourth grade state mandated TAAS test are also chosen. All of the items in the pool were prepared by a professional testing company and reviewed by mathematics professionals and the TEA's departments of assessment and mathematics for content validity in the three mathematical domains of concepts, operations, and problem solving. All three domains were included on the researcher's TAAS Diagnostic Test. The researcher chose to use this TAAS Mathematics Diagnostic Test because, taken collectively, these test items measured the specified fourth grade curriculum more accurately than any norm-referenced test (such as the NAPT or ITBS). According to the TEA, the TAAS items are directly correlated to the Texas Essential Elements for mathematics (TEA, 1991). In addition, the items on the TAAS Mathematics Diagnostic Test require children to use application and higher-order thinking skills in a problem solving context - skills subject to impact by writing-to-learn activities - rather than isolated computational skills. In short, the TAAS-type items are more in line with the NCTM Standards and are a better indicator of student progress than traditional norm-referenced measures of student performance, according to the new paradigm of mathematics instruction.

Student attitude toward mathematics was measured by mathematics items on the Survey of School Attitudes. This is a sixty item inventory with Likert-type scale response choices. This survey was developed to provide reliable
information on children's reactions to four major areas of the school curriculum: reading and language arts, mathematics, science, and social studies. Children indicate whether they like, dislike, or are neutral toward different activities in the four areas. While there is no time limit, the estimated time required to respond is twenty-five minutes.

On the Survey of School Attitudes, the sum of a student's responses to a sample of activities typically encountered in a curricular area is considered an indication of the student's overall affective reaction to that area. The Survey yields scores on four scales, one for each of the four curricular areas. Each scale includes 15 items, distributed throughout the test booklet so that students will react to each item independently rather than develop a response set to a group of similar items. The Survey items were chosen to be representative both of school activities and of school-learned skills and concepts used in everyday life. The mathematics-related items were scored and analyzed for the purposes of this study. The mathematics scale covers geometry and measurement, numeration concepts, computation, and problem solving. Form A was used as the pretest, and Form B was used as the posttest.

Reliability studies of the Survey indicated that the various scales were reasonably reliable (Hogan, 1975). As to the issue of validity, the author determined that "[c]ontent validity is not sufficient for an instrument such as the SSA" (p.8, author's italics). Furthermore, the author states that while "[v]alidity is never definitively or conclusively established" (p. 12), he believes that "there is reasonably good differentiation in what is being measured and this differentiation is consistent with a content analysis of the Survey items, suggesting that the Survey is indeed measuring what it is designed to measure" (p.12). The authors
also concluded that the data indicate that the Survey does measure separate attitudinal dimensions, not a single, global attitude towards school.

Research Design and Treatment

Staff development, modeling, and support were given to the teachers of students in the treatment group as the teachers learned how to implement writing-to-learn tasks into their mathematics instruction. The fourth grade teachers in the treatment group were assisted in choosing, adapting, and designing writing-to-learn tasks in order to incorporate appropriate assignments into their teaching of fourth grade mathematics concepts. The writing tasks were of three basic types: transactional, expressive, and poetic. While the teachers in this study generally assigned the same writing tasks to their classes, they used their discretion to modify assignments to meet the needs of individual students in their classes. Some of the writing-to-learn tasks used by the teachers in this study targeted problem solving and some focused on the concepts of fractions and geometry, concepts which had not been taught earlier in the year, but fell into the natural teaching sequence at the time of the study, according to the fourth grade district curriculum guide and mathematics text. In the fourth grade instructional sequence, problem solving assignments are frequently interspersed among lessons introducing and developing new concepts. These problem solving activities may be targeting some of the new concepts, but are more likely to require previously learned concepts. This focus on problem solving using familiar concepts provided students not only reinforcement and review of important concepts, but also opportunities to apply these concepts in new situations and to use critical thinking skills. The writing-to-learn activities were easily incorporated into problem solving instruction, but also naturally
complemented the introduction of new concepts. The writing-to-learn activities were used for a ten week period and were integrated into the mathematics instruction two or three times per week.

Staff development in the use of writing-to-learn as an instructional technique consisted of two stages. The first stage was baseline training that was given to all elementary teachers in the district in the use of writing heuristics or strategies as an effective method for beginning writing-to-learn strategies in all disciplines. Writing heuristics are structured activities that help students find out what they already know about a topic, what they need to know about it, and how to organize new information as they obtain it. Examples of writing heuristics are listing, clustering or webbing, questioning (who, what, where, when, why, how), and "cubing" of a topic (describe it, compare it, associate it, analyze it, apply it, argue for or against it). This baseline training consisted of a ninety minute inservice and was held four months prior to this study. The training was given at the request of the district's assistant superintendent for curriculum and instruction.

The second phase of staff development was given only to the teachers of the treatment group. These teachers spent two afternoons after school with the researcher reviewing studies that reported achievement gains or improvement of student attitude toward mathematics and examining concrete examples of writing tasks that could be used in their mathematics instruction. While these sessions were informal, they focused on the practicality and the variety of the writing tasks and the ease with which teachers could implement them. Teachers were given examples of the different types of writing-to-learn tasks, the benefits of each, and instances in which the teachers might use the various kinds. The teachers were encouraged to choose a variety of writing tasks, many of which were written by
the researcher, or to adapt or to design their own. In addition, the teachers committed to requiring their students to keep a math journal in which writing assignments would be kept and reviewed on a regular basis. The teachers were especially enthusiastic about using math journals and were eager to incorporate the reflective kinds of writing prompts that the literature has reported on so favorably.

As the first activity with students, the researcher modeled a mathematics lesson that required writing as an integral part of the instruction for each class in the treatment group. The lesson is described in Appendix B. After the initial lesson, the teachers in the treatment group met weekly with the researcher for assistance in mathematics lesson plan writing to ensure that their instruction included appropriate writing tasks. During these weekly sessions, the researcher either wrote lesson plans with writing tasks integrated into them for the teachers or added to the teachers' own mathematics lesson plans three or four writing prompts from which the teachers could choose or adapt. All teachers were encouraged to use at least two or three writing assignments per week. See examples of the different types of writing tasks in Appendix C.

In addition to guiding the teachers in selecting or designing their own writing tasks, teachers also were supported by the researcher in responding to their students' writing. The teachers and the researcher read students' journals or other writing assignments, wrote back to the students when appropriate, and "published" (posted) students' work, with the students' permission, especially when the writing was creative in nature. Students also shared writing experiences with peers as they explained methods of solving problems or analyzed what they learned about the concepts they were studying.
Treatment of Data

To evaluate the effect of using writing-to-learn tasks in mathematics on achievement and attitude, students in both the treatment and contrast groups completed instruments used to test hypotheses of the study. The week before the study began, students in the treatment group and the control group were administered Form A of the Survey of School Attitudes and the TAAS Diagnostic Test, both of which served as pretests for statistical analysis. At the end of the study, students completed Form B of the Survey of School Attitudes to determine any difference in attitude toward mathematics between the two student groups. The TAAS Diagnostic Test was also administered as a posttest and results were used to evaluate any difference in mathematics achievement between the two groups.

The achievement and attitude gains for females at each school were disaggregated. Because the literature reports that in early adolescent years, effort and interest in mathematics of girls begins to wane (Everybody Counts, 1989), this study searched for statistically significant differences in female attitudes and achievement effects after the writing-to-learn tasks have been used. This study also attempted to find any statistically significant differences in the attitude and achievement effects for low achieving students after using writing-to-learn activities in mathematics.

Hypotheses one through six were tested using analysis of covariance (ANCOVA) with the pretest scores as the covariant. Analysis of covariance was used because the study involved existing intact groups which may have differed in their previous background of mathematics concepts and their attitudes toward mathematics. ANCOVA adjusts the scores statistically to account for the possibility of preexisting conditions. The covariants, dependent variables, and
independent variables for each of the hypotheses are presented in Table 4. For each hypothesis, a table is given that summarizes the results of pretest and posttest measures and the significance of the difference between means.

Table 4

*Variables in Hypotheses One Through Six*

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Sample</th>
<th>Covariant</th>
<th>Dependent Variable</th>
<th>Independent Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Full</td>
<td>pretest-ACH</td>
<td>posttest-ACH</td>
<td>treatment</td>
</tr>
<tr>
<td>2</td>
<td>Female</td>
<td>pretest-ACH</td>
<td>posttest-ACH</td>
<td>treatment</td>
</tr>
<tr>
<td>3</td>
<td>Low achieving</td>
<td>pretest-ACH</td>
<td>posttest-ACH</td>
<td>treatment</td>
</tr>
<tr>
<td>4</td>
<td>Full</td>
<td>pretest-ATT</td>
<td>posttest-ATT</td>
<td>treatment</td>
</tr>
<tr>
<td>5</td>
<td>Female</td>
<td>pretest-ATT</td>
<td>posttest-ATT</td>
<td>treatment</td>
</tr>
<tr>
<td>6</td>
<td>Low achieving</td>
<td>pretest-ATT</td>
<td>posttest-ATT</td>
<td>treatment</td>
</tr>
</tbody>
</table>
CHAPTER 4

PRESENTATION AND ANALYSIS OF DATA

At the conclusion of the treatment, students' mathematics achievement and attitude toward mathematics were measured and data were analyzed according to the instruments described in Chapter 3 to determine any differences between the treatment and contrast groups. Each hypothesis stated in Chapter 1 of the study was tested.

Achievement in mathematics was measured using the TAAS Mathematics Diagnostic Test. This test was given as a pretest just before treatment began and as a posttest after the treatment was completed. Analysis of covariance was used to determine if there were any significant differences between achievement measures of the two groups after treatment, using the pretest scores as the covariant and the posttest scores as the dependent variable.

The Survey of School Attitudes was used to determine any differences in attitude toward mathematics following the treatment. Form A of the Survey of School Attitudes was administered to the students as the pretest before the treatment commenced and Form B of the Survey of School Attitudes was given as a posttest after the treatment ended. Analysis of Covariance was used to determine if there were any significant differences between measures of attitude toward mathematics of the two groups after the treatment, using pretest measures from the Survey of School Attitudes Form A as a covariant and the posttest measures from Form B as the dependent variable.
TAAS Mathematics Diagnostic Test
Measure of Student Achievement

The TAAS Mathematics Diagnostic Test was given as a pretest to both groups of students before the treatment began and was repeated as a posttest after treatment was completed. Analysis of covariance was used to test each hypothesis relative to achievement measures, with pretest measures serving as the covariant in order to control for possible pre-existing differences.

Hypothesis 1: The mean score on the fourth grade TAAS Mathematics Diagnostic Test for a group of students who used writing-to-learn tasks in mathematics will be significantly higher than the mean score of a contrast group of students who did not use the same writing-to-learn tasks in mathematics. The hypothesis was tested using ANCOVA. In order to control for possible pre-existing differences, the pretest score was the covariant, while the posttest score was the dependent variable. Table 5 summarizes the results of pretest and posttest measures and data analysis. Analysis revealed a p-value of 0.0003, indicating a significant difference in achievement between the two groups after the treatment.

Table 5

*Comparison of Posttreatment Scores of the Two Student Groups on TAAS Mathematics Diagnostic Test, with Pretreatment Scores as a Covariant*

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Std. Dev.</th>
<th>Posttest Mean</th>
<th>Std. Dev.</th>
<th>F-Ratio</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>125</td>
<td>36.376</td>
<td>6.806</td>
<td>41.536</td>
<td>6.058</td>
<td>39.36</td>
<td>0.0003</td>
</tr>
<tr>
<td>Contrast</td>
<td>118</td>
<td>37.653</td>
<td>7.499</td>
<td>38.424</td>
<td>9.007</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Hypothesis 2: The mean score on the fourth grade TAAS Mathematics Diagnostic Test for female fourth grade students who used writing-to-learn tasks in mathematics will be significantly higher than the mean score of female fourth grade students who did not use writing-to-learn tasks in mathematics. The hypothesis was tested using ANCOVA. In order to control for pre-existing differences, the pretest score was the covariant, while the posttest score was the dependent variable. Table 6 summarizes the results of pretest and posttest measures and data analysis. Analysis revealed a p-value of 0.001, indicating a significant difference in achievement between the two groups after the treatment.

Table 6

**Comparison of the Posttreatment Scores of the Two Female Groups on TAAS Mathematics Diagnostic Test, with Pretreatment Scores as a Covariant**

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Std. Dev.</th>
<th>Posttest Mean</th>
<th>Std. Dev.</th>
<th>F- Ratio</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>61</td>
<td>36.852</td>
<td>6.300</td>
<td>42.508</td>
<td>5.233</td>
<td>12.06</td>
<td>0.001</td>
</tr>
<tr>
<td>Contrast</td>
<td>59</td>
<td>36.915</td>
<td>7.994</td>
<td>38.881</td>
<td>9.405</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hypothesis 3: The mean score on the fourth grade TAAS Mathematics Diagnostic Test for low achieving fourth grade students who used writing-to-learn tasks in mathematics will be higher than the mean score of low achieving fourth grade students who did not use writing-to-learn tasks in mathematics. The hypothesis was tested using ANCOVA. In order to control for pre-existing differences, the pretest score was the covariant, while the posttest score was the dependent variable. Table 7 summarizes the results of pretest and posttest
measures and data analysis. Analysis revealed a p-value of 0.0002, indicating a significant difference in achievement between the two groups after the treatment.

Table 7

Comparison of the Posttreatment Scores of the Two Low Achieving Groups on TAAS Mathematics Diagnostic Test, with Pretreatment Scores as a Covariant

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Std. Dev.</th>
<th>Posttest Mean</th>
<th>Std. Dev.</th>
<th>F-Ratio</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>45</td>
<td>29.089</td>
<td>5.067</td>
<td>36.667</td>
<td>6.090</td>
<td>25.23</td>
<td>0.0004</td>
</tr>
</tbody>
</table>

Survey of School Attitudes - Measures of Attitude Toward Mathematics

Student attitude toward mathematics was measured for both the treatment and contrast groups, both before and after the treatment. The Survey of School Attitudes was used as the instrument. Form A of the Survey of School Attitudes was used as a pretest, and Form B was used as a posttest. In each case, the mathematics subtest was scored and used as a basis for analysis. Analysis of Covariance (ANCOVA) was used to test the hypothesis relative to student attitude toward mathematics. Pretest measures served as the covariant, in order to control for possible pre-existing differences.

Hypothesis 4: The mean score on a mathematics attitude scale, as measured by the Survey of School Attitudes, for a group of fourth grade students who used writing-to-learn tasks in mathematics will be significantly higher than the mean score of a contrast group of fourth grade students who did not use
writing-to-learn tasks in mathematics. The hypothesis was tested using ANCOVA. In order to control for possible pre-existing differences, the pretest score was the covariant, while the posttest score was the dependent variable. Table 8 summarizes the results of pretest and posttest measures and data analysis. Analysis revealed a $p$-value of 0.124, which exceeds the 5% level of significance, indicating there was no significant difference in attitude toward mathematics between the two groups after the treatment.

Table 8

*Comparison of the Posttreatment Scores of the Two Student Groups on Survey of School Attitudes, Mathematics, with Pretreatment Scores as a Covariant*

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Std. Dev.</th>
<th>Posttest Mean</th>
<th>Std. Dev.</th>
<th>F-Ratio</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>125</td>
<td>15.864</td>
<td>6.985</td>
<td>15.520</td>
<td>7.884</td>
<td>2.38</td>
<td>0.124</td>
</tr>
<tr>
<td>Contrast</td>
<td>118</td>
<td>17.610</td>
<td>7.976</td>
<td>18.008</td>
<td>8.337</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hypothesis 5: The mean score on a mathematics attitude scale, as measured by the Survey of School Attitudes, for a group of female fourth grade students who used writing-to-learn tasks in mathematics will be significantly higher than the mean score of a contrast group of female fourth grade students who did not use writing-to-learn tasks in mathematics. The hypothesis was tested using ANCOVA. In order to control for possible pre-existing differences, the pretest score was the covariant, while the posttest score was the dependent variable. Table 9 summarizes the results of pretest and posttest measures and data analysis. Analysis revealed a $p$-value of 0.324, which exceeds the 5% level.
of significance, indicating there was no significant difference in attitude toward mathematics between the two groups after the treatment.

Table 9

Comparison of the Posttreatment Scores of the Two Female Groups on Survey of School Attitudes, Mathematics, with Pretreatment Scores as a Covariant

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Std. Dev.</th>
<th>Posttest Mean</th>
<th>Std. Dev.</th>
<th>F-Ratio</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>61</td>
<td>15.820</td>
<td>7.025</td>
<td>15.508</td>
<td>8.332</td>
<td>0.98</td>
<td>0.324</td>
</tr>
<tr>
<td>Contrast</td>
<td>59</td>
<td>17.390</td>
<td>8.801</td>
<td>17.847</td>
<td>9.057</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Hypothesis 6: The mean score on a mathematics attitude scale, as measured by the Survey of School Attitudes, for a group of low achieving fourth grade students who used writing-to-learn tasks in mathematics will be significantly higher than the mean score of a contrast group of low achieving fourth grade students who did not use writing-to-learn tasks in mathematics. The hypothesis was tested using ANCOVA. In order to control for possible pre-existing differences, the pretest score was the covariant, while the posttest score was the dependent variable. Table 10 summarizes the results of pretest and posttest measures and data analysis. Analysis revealed a p-value of 0.066, which exceeds the 5% level of significance, indicating there was no significant difference in attitude toward mathematics between the two groups after the treatment.
Table 10

Comparison of the Posttreatment Scores of the Two Low Achieving Groups on
Survey of School Attitudes, Mathematics, with Pretreatment Scores as a
Covariant

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Std. Dev.</th>
<th>Posttest Mean</th>
<th>Std. Dev.</th>
<th>F-Ratio</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>45</td>
<td>15.200</td>
<td>7.443</td>
<td>12.978</td>
<td>7.524</td>
<td>3.48</td>
<td>0.066</td>
</tr>
<tr>
<td>Contrast</td>
<td>37</td>
<td>18.243</td>
<td>8.067</td>
<td>17.514</td>
<td>8.238</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Further Exploration and Analysis of Data

While the achievement measures in this study dealt with mean scores on
the TAAS Mathematics Diagnostic Test, the researcher chose to subject a subset
of the test items to a separate analysis for the following reason: Some of the
writing-to-learn tasks used in this study targeted problem solving, one of the
strands of mathematics that is taught all year long, and some of the writing
activities focused on the concepts of fractions and geometry, concepts which
were taught primarily during the study. While the TAAS Mathematics Diagnostic
Test is composed primarily of problem solving questions, seven questions out of
the total 51 dealt specifically with fractions or geometry. Using ANCOVA, with
the pretest scores on the fraction and geometry items serving as the covariant,
the posttest scores of the treatment group on these questions were compared to
those of the contrast group. Results of this analysis are given in Table 11 below.
Analysis revealed a p-value of 0.024, indicating a significant difference in
achievement on these items between the two groups at the 5% level of
significance after the treatment.
Table 11

Comparison of Posttreatment Scores of the Two Student Groups on Fraction and Geometry Items, with Pretreatment Scores as a Covariant

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Std. Dev.</th>
<th>Posttest Mean</th>
<th>Std. Dev.</th>
<th>F-Ratio</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>125</td>
<td>4.944</td>
<td>1.131</td>
<td>6.152</td>
<td>.959</td>
<td>5.16</td>
<td>0.024</td>
</tr>
<tr>
<td>Contrast</td>
<td>118</td>
<td>5.483</td>
<td>1.182</td>
<td>5.890</td>
<td>1.280</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When the two sub-groups were compared, mixed results were obtained. There was no significant difference in achievement gains for the female students in the treatment group, as compared to the females in the contrast group, on the geometry and fraction items. However, the low achieving students in the treatment group, as compared to the low achievers in the contrast group, had significant gains on this subset of items. Using ANCOVA, with the pretest scores on the geometry and fraction items serving as the covariant, the posttest scores of the low achieving students in the treatment group on these questions were compared to those of the low achievers of the contrast group. Results of this analysis are given in Table 12 below. Analysis revealed a p-value of 0.026, indicating a significant difference in achievement on these items between the two groups at the 5% level of significance after the treatment. Evans (1984) study with fifth graders who used writing-to-learn tasks to teach multiplication and geometry concepts found similar results: students with the lowest pretest scores made significant gains.
Table 12

*Comparison of Posttreatment Scores of the Low Achieving Students of the Two Groups on Fraction and Geometry Items, with Pretreatment Scores as a Covariant*

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Pretest Mean</th>
<th>Std. Dev.</th>
<th>Posttest Mean</th>
<th>Std. Dev.</th>
<th>F-Ratio</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment</td>
<td>45</td>
<td>4.156</td>
<td>.952</td>
<td>5.933</td>
<td>1.031</td>
<td>5.12</td>
<td>0.026</td>
</tr>
<tr>
<td>Contrast</td>
<td>37</td>
<td>4.541</td>
<td>1.282</td>
<td>5.162</td>
<td>1.659</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Because the number of geometry and fraction items is small, one must be cautious in interpreting these results. However, the increase in the mean scores on the entire TAAS Diagnostic Test is consistent with the results found in Schubert's (1987) study with fourth graders who used writing-to-learn activities as they studied fractions. Schubert reports a "carryover" benefit from her use of writing-to-learn about fractions. On subsequent pretests, her students consistently scored higher on the problem solving, even though the problem solving required the use of concepts they had not yet studied. She suggests that the writing activities gave her students enough practice and confidence in thinking through their problems that problem solving no longer intimidated them.
CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

The purpose of this study was to determine the effects of implementing writing-to-learn tasks in mathematics instruction on fourth grade students' achievement and attitude toward mathematics. Fourth grade mathematics teachers and students from two closely matched elementary schools participated in the study. Teachers and students at one of the campuses served as the treatment group; teachers and students at the other campus were the contrast group. The teachers in the treatment group were provided with staff development, modeling, and support in the use of writing-to-learn tasks in mathematics. After the initial staff development, teachers in the treatment group regularly involved their students in writing activities in mathematics for a ten week period. Following the treatment, the study investigated any differences between the treatment and contrast groups in mathematics achievement and attitude toward mathematics, as measured by the instruments used in this study.

The treatment group consisted of the fourth grade mathematics teachers and 125 students at one campus. The contrast group was composed of the fourth grade mathematics teachers and 118 students at another campus. Having the treatment group on one campus facilitated the team planning and collegial support that has become essential for each team's function.

Just before the treatment began, students in both the treatment and contrast groups were administered the TAAS Mathematics Diagnostic Test, a mathematics criterion-referenced test similar to the state mandated TAAS test,
and Form A of the Survey of School Attitudes. These instruments served as pretests to measure mathematics achievement levels and attitudes toward mathematics.

The professional development and support for the teachers participating in the study consisted of a variety of formats. In both formal and informal sessions, the researcher worked with the teachers in the treatment group to design writing-to-learn mathematics tasks and lesson plans, modeled lessons in which writing was an integral part, responded to students' writing, reviewed student progress with the teachers and provided them with support as the writing activities were implemented.

Different types of writing-to-learn tasks were incorporated into the mathematics instruction two or three times per week. Specifically, the concepts of geometry and fractions and problem solving were targeted for integration of writing tasks of three basic types: reflective, poetic, and transactional. Students kept math journals for daily writing in addition to other writing assignments that were assigned by the teachers. While the four teachers in this study generally assigned the same writing tasks to their classes, the teachers were given the discretion to modify assignments to meet the needs of individual students in their classes. When appropriate, students shared their writing with other students, their teacher, and family members. Both the teachers and the researcher frequently responded to students' writings. Following the treatment, students completed two instruments as posttests: form B of the Survey of School Attitudes and the TAAS Mathematics Diagnostic Test.
Summary of Findings

Achievement and attitude scores of the treatment and contrast groups were compared following the treatment. In addition, separate analyses were made of the scores of the achievement and attitude of two sub-groups: 1) measures of the female students in the treatment and contrast were compared, and 2) measures of the low achieving students of the two groups were compared. Analysis of covariance (ANCOVA) was used to analyze both the achievement and attitude measures for the whole groups and the two sub-groups to determine if there were any significant differences in the measures after treatment. In the ANCOVA, pretest scores served as the covariant to accommodate any initial differences between the groups being compared; posttest scores served as the dependent variable. The findings resulting from the analysis of the statistical data in this study were the following:

1. A significant difference (p-value of 0.003) was found between the mean achievement scores of the students who used writing-to-learn activities in mathematics and the students who did not use writing-to-learn tasks in mathematics.

2. A significant difference (p-value of 0.001) was found between the mean achievement scores of female students who used writing-to-learn activities in mathematics and female students who did not use writing-to-learn tasks in mathematics.

3. A significant difference (p-value of 0.0004) was found between the mean achievement scores of low achieving students who used writing-to-learn activities in mathematics and low achieving students who did not use writing-to-learn tasks in mathematics.
4. No significant difference was found in the mean attitude scores of students who used writing-to-learn activities in mathematics and students who did not use writing-to-learn tasks in mathematics.

5. No significant difference was found in the mean attitude scores of female students who used writing-to-learn activities in mathematics and female students who did not use writing-to-learn tasks in mathematics.

6. No significant difference was found in the mean attitude scores of low achieving students who used writing-to-learn activities in mathematics and low achieving students who did not use writing-to-learn tasks in mathematics.

Conclusions

In summary, the use of writing-to-learn tasks in mathematics instruction resulted in an increase in students' mathematics achievement, as measured by the instruments used in this study, but did not positively affect students' attitude toward mathematics. Significant achievement gains were also found in two sub-groups - female students and low achieving students - of the treatment group who used writing-to-learn tasks in mathematics, but neither of these two sub-groups improved in attitude toward mathematics.

The improved scores in achievement, as opposed to attitude, may be attributable to the emphasis placed upon producing high scores on the state-mandated TAAS tests administered each spring to fourth grade students. Results of the TAAS tests are used for high-stakes decisions, such as ranking of schools at the statewide and district levels. Competition for high scores among schools in the district is keen. Each year, much of the instruction in the spring is planned with the TAAS test in mind. Teachers in this study, as well as the rest of the district, encourage their students to take all TAAS related assignments very
seriously. While most teachers try not to pressure their students unduly, they make it clear to the students that these tests and related assignments are of paramount importance and that they expect all students to read, analyze, and carefully answer each question.

Teachers in both groups were more relaxed about the attitude surveys than they were about the achievement tests, perhaps because attitude measures are not used for accountability purposes as are the TAAS related measures. Teachers from both the treatment and contrast groups reported that their students enjoyed taking the attitude pretest early in the spring and viewed the survey as novel. However, by the time the students were administered the attitude posttest at the end of the year, the teachers remarked that their students were no longer enthusiastic about answering the attitude survey. This lack of interest may be attributed to the amount of standardized testing and its attendant tension and may explain why the scores of the treatment group declined slightly.

Of particular interest to the researcher was the professional growth and change in attitude towards mathematics instruction exhibited by the teachers in the treatment group as the project progressed. Authors of successful professional development programs (Fullen & Pomfret, 1977; Garmston, 1987; Glatthorn, 1987b; Wood, 1989) contend that when teachers are active participants in their training, when they are allowed to make significant choices about their own learning, when they collaborate with and coach each other, and when they adapt new learning to fit their own needs, classroom application of the training is more likely to occur. In this study, the teachers were encouraged to learn cooperatively, design or adjust the lessons, guide the format of the follow-up sessions, and coach each other, all of which promoted ownership of the project and empowerment of the teachers.
This change in teacher attitude and eventual ownership of the project began gradually. At the initial planning sessions, the teachers, while enthusiastic about using this new technique of writing-to-learn in their mathematics instruction, were still very self-conscious about their planning and what could be expected of their students. The teachers were very conservative in wanting to "cover" the material in the textbook. Several of the teachers were even somewhat apologetic about their students' initial attempts at writing. However, as the professional development sessions progressed, and the researcher was supportive of the teachers' ideas, the teachers became more confident and more willing to take risks with their students. As the study progressed, the teachers took more responsibility for planning the writing tasks and depended less on the researcher to supply the writing prompts and lesson plans. No longer did the teachers make excuses for some of their students writing. In fact, they were particularly pleased with their students' journal writing and the pride their students showed in them. In general, mathematics instruction became more innovative and less textbook dependent, even when writing-to-learn tasks were not being discussed. As the next school year began, much of this enthusiasm has remained with these teachers. Teachers in this study have continued to use journal writing with their students in mathematics; they have requested several innovative mathematics resources from the researcher; they have attended inservices on integrating children's literature and writing in mathematics and on using new mathematics computer software. Their collegiality and support for each other remains high.
Recommendations

Students who used writing-to-learn tasks in mathematics made significant gains in achievement over a relatively short period of time. The teachers in the treatment group reported positive experiences as they planned and involved their students in this study. In addition, journal writing has become a regular part of these fourth grade teachers' mathematics instruction. Thus, for this district, the researcher recommends that writing-to-learn in mathematics become a regular part of all fourth grade teachers' mathematics instruction. Specifically, the researcher recommends that fourth grade teachers implement journal writing in mathematics, since the use of journals requires minimum training and short periods of classroom time. With the district's focus on process writing, principals encourage teachers to integrate writing into all subject areas; adding mathematics journal writing is a natural extension of the district's writing emphasis. In order to promote this district-wide implementation, the researcher has arranged for the district's writing committee, a group of nine teachers responsible for conducting staff development and providing technical support in writing, to include sessions on math journal writing with emphasis on expressive writing tasks.

In addition, the researcher recommends that mathematics supervisors and specialists throughout the nation promote writing-to-learn in mathematics at the elementary level, especially through the use of journal writing. Articles in national mathematics and teaching journals, such as The Arithmetic Teacher and Instructor, are possible vehicles for communicating to a national audience this researcher's results, along with student work samples and reflective comments from both the teachers and students involved in the study.
As for recommendations for future research, this researcher suggests that further studies on writing-to-learn in mathematics focus on affecting student attitude toward mathematics. It may be more important to improve students' attitude toward mathematics before more substantial, long-term improvement in mathematics achievement can be effected. In addition, it is recommended that further studies in writing-to-learn in mathematics be conducted at grade levels other than fourth grade. Also, more authentic assessments, instead of the traditional multiple-choice type, may be required to measure mathematics achievement once writing-to-learn tasks have been implemented. Especially with the new emphasis on expanding the scope of student achievement measures to include open-ended performance-based assessment, writing-to-learn in mathematics may attain new status as the most productive way to effect achievement gains on these new kinds of assessments.

Possible questions to be answered by future research include the following:

1. Would a decrease in standardized testing anxiety affect student attitude toward mathematics?

2. Would the use of writing-to-learn tasks over a broader range of mathematics topics throughout the year affect students' mathematics attitude, as well as achievement?

3. Would writing-to-learn in mathematics affect achievement in one strand of mathematics, such as probability or numeration, more than others?

4. Would the use of writing-to-learn tasks in mathematics at other grade levels affect students' mathematics attitude and/or achievement? Is there an optimum range of grade levels, i.e., primary, intermediate, middle school, high
school, college, in which writing-to-learn would have the greatest effect on student attitude and/or achievement?

5. Is there a cumulative effect on mathematics achievement and/or attitude from using writing-to-learn in mathematics throughout the elementary and/or middle school and/or high school years?

6. Would the use of writing-to-learn tasks affect students' achievement on performance-based mathematics assessments, as well as more traditional forms of assessment, and improve students' attitude toward mathematics?

7. Would students who use writing-to-learn tasks in mathematics score higher on science and social studies performance-based assessments, such as those that are being field-tested by the Texas Education Agency?

8. Would the use of one type of writing, such as expressive writing, affect students' mathematics attitude and/or achievement more than other types of writing, such as transactional or poetic writing, or do students need to use a variety of writing types to improve their attitude and/or achievement?
APPENDIX A

TAAS MATHEMATICS DIAGNOSTIC TEST
1. Each year the average American eats one thousand, four hundred seventeen pounds of food. How is this number written?

A. 100,400,017  
B. 1,400,170  
C. 14,170  
D. 1,417

2. A family is lining up from shortest to tallest for a picture. The parents are Kay, who is 65 inches tall, and Mike, who is 74 inches tall. The children are Lee, who is 66 inches tall, and Bill, who is 54 inches tall. In what order should they line up for the picture?

A. Bill Lee Kay Mike  
B. Kay Mike Bill Lee  
C. Bill Kay Lee Mike  
D. Kay Mike Lee Bill

3. Which decimal tells how much is shaded?

A. 1.2  
B. 1.8  
C. 10.8  
D. 12.0
4. What is the value of the 5 in 1,567,491?
   A. 5 hundred
   B. 5 thousand
   C. 5 hundred thousand
   D. 5 million

5. What is 3,756 rounded to the nearest hundred?
   A. 3,700
   B. 3,750
   C. 3,760
   D. 3,800

6. Which figure has \( \frac{1}{3} \) shaded?
   A.  
   B.  
   C.  
   D.  

7. Which figure appears to be congruent (same size, same shape) to \( \triangle ABC \)?
   A.  
   B.  
   C.  
   D.  
8. The locker doors for 5 students are shown.

Which students have lockers that are marked with even numbers?

A. Betsy, Carl
B. Betsy, Carl, Donna, Evan
C. Abe, Donna, Evan
D. Abe, Betsy

9. Point M best represents what number?

A. 4.1
B. 3.7
C. 3.5
D. 3.2

10. Which point best represents 4.7 on the number line?

A. K
B. M
C. N
D. P
11. The figures are shaded to show 2 equivalent fractions.

Which of these is equivalent to \( \frac{1}{2} \)?

A. \( \frac{1}{6} \)
B. \( \frac{1}{4} \)
C. \( \frac{3}{6} \)
D. \( \frac{3}{4} \)

12. The drinking glass has the shape of a ____________.

A. circle
B. cone
C. cylinder
D. sphere
13. The models are shaded to show 2 fractions.

\[ \begin{array}{c}
\begin{array}{c}
\text{Model 1} \\
\text{Model 2}
\end{array}
\end{array} \]

The models show that - -

A. \( \frac{1}{4} < \frac{1}{6} \)

B. \( \frac{1}{4} = \frac{1}{6} \)

C. \( \frac{3}{4} = \frac{5}{6} \)

D. \( \frac{3}{4} < \frac{5}{6} \)

14. For a game in P.E. class, the teacher arranged the students in rows. The first row contained 2 students. The second row had 5 students, the third row had 8 students, and the fourth row had 11 students in it. If this pattern continues, how many students will be in the sixth row?

A. 13
B. 14
C. 17
D. 20
15. If 4 times a number is 76, which expression could be used to find the number?

A. $4 \times 76$
B. $4 + 76$
C. $76 \div 4$
D. $76 - 4$

16. Which letter has a line of symmetry?

A. M
B. S
C. F
D. G

17. What number makes the sentence true?

$$(2 + 6) + 4 = 2 + (6 + \square)$$

A. 4
B. 6
C. 8
D. 10

18. The Rogers family traveled 298 miles from San Antonio to Big Springs and 319 miles from Big Springs to Austin. How many miles did they travel?

A. 501 mi
B. 507 mi
C. 606 mi
D. 617 mi
19. How many faces does a rectangular prism have?

A. 12
B. 6
C. 4
D. 2

20. The rectangular piece of land is to be used for a state park.

What is the perimeter of the piece of land?

A. 23 miles
B. 46 miles
C. 56 miles
D. 126 miles
21. The graph shows the favorite playground equipment at Stephenson Elementary School.

<table>
<thead>
<tr>
<th>Favorite Playground Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of students</td>
</tr>
<tr>
<td>Monkey Bars</td>
</tr>
<tr>
<td>Swings</td>
</tr>
<tr>
<td>Merry-Go-Round</td>
</tr>
</tbody>
</table>

How many more students chose the monkey bars than chose the swings as their favorite playground equipment?

A. 125  
B. 75  
C. 50  
D. 40

22. In a total of 10 spins, which shape will the spinner probably point to the greatest number of times.

A. △  
B. ★  
C. □  
D. □
23. Which is the best estimate of the area of the polygon drawn on the grid?

A. 28 square units
B. 24 square units
C. 21 square units
D. 17 square units

24. Sue's family can buy a new car without air conditioning for $8,500 or with air conditioning for $9,250. How much will they save on the cost of the car if they buy the car without air conditioning?

A. $750
B. $850
C. $1,300
D. $1,700

25. \(234 + 45 + 761 =\)

A. 930
B. 1,040
C. 1,345
D. 1,445
26. The diagram shows a rectangular kitchen floor. Each tile is 1 square foot.

![Diagram of a rectangular floor with tiles]

What is the area of the floor?

A. 15 sq ft  
B. 30 sq ft  
C. 45 sq ft  
D. 54 sq ft

27. Michelle practiced baseball for 1 hour and 45 minutes on Saturday. How many minutes did she practice?

A. 145 minutes  
B. 105 minutes  
C. 100 minutes  
D. 69 minutes

28. Bob selected 4 items in a store. The lowest-priced item was $3 and the highest-priced item was $8. Before tax is added, what is a reasonable total for the cost of the items?

A. less than $8  
B. between $8 and $12  
C. between $12 and $32  
D. more than $32
29. The graph shows the tide levels during a six-hour period at the beach.

During which time period did the tide rise the greatest number of meters?

A. Between 10 and 11
B. Between 11 and 12
C. Between 12 and 1
D. Between 1 and 2

30. \[ \frac{48}{x} = 16 \]

A. 296
B. 336
C. 768
D. 774
31. Raphael's family plans to drive 146 kilometers from Laredo to Monterey, 600 kilometers from Monterey to Mexico City, and 249 kilometers from Mexico City to Acapulco. How many kilometers will they have driven when they arrive in Acapulco?

A. 995 km  
B. 986 km  
C. 985 km  
D. 850 km

32. A package contains 48 cookies. If there are 24 packages to a case, how many cookies are there in each case?

A. 1,152  
B. 1,052  
C. 72  
D. 62

33. Mark divided 36 marbles into 4 equal groups. How many marbles were in each group?

A. 33  
B. 12  
C. 9  
D. 6

34. Rachel is older than Joe. Joe is younger than Sam. Mary is older than Rachel. Which of the following is a reasonable conclusion?

A. Mary is older than Joe.  
B. Mary is the youngest.  
C. Sam is younger than Joe.  
D. Rachel is the oldest.
35. \( 2,000 - 699 = \)
   A. 1,401
   B. 1,399
   C. 1,301
   D. 1,299

36. \( 38 + 7 = \)
   A. 50 R3
   B. 5 R3
   C. 5
   D. 4

37. A baby elephant weighing 577 pounds and a gorilla weighing 281 pounds are going to be shipped to a zoo. What is the best estimate of their combined weights?
   A. 300 pounds
   B. 400 pounds
   C. 900 pounds
   D. 1,200 pounds

38. Sam’s father was able to average 59 miles per hour on a 6-hour trip. Which is the best estimate of the number of miles he drove during the 6 hours?
   A. Less than 70 mi
   B. Between 70 and 100 mi
   C. Between 200 and 300 mi
   D. Between 350 and 400 mi
39. Award trophies cost $8 each. If the art show needs 4 trophies, about how much will the art department need to buy them?

A. $5  
B. $15  
C. $25  
D. $35

40. Brad ran and finished a 12-kilometer race. The race course forms a triangle as shown in the diagram. The distance along Third Street was 3 kilometers and the distance along Apple Gate Road was 5 kilometers.

What distance did Brad run along Main Avenue?

A. 7 km  
B. 6 km  
C. 5 km  
D. 4 km
41. Which sentence tells one way to find the area in square units of the shaded walkway around the rectangular garden?

A. Count the unshaded squares only.
B. Count the shaded squares only.
C. Count one row of squares along the sides of the small rectangle.
D. Count all the squares in the figure.

42. \[2.25 - 1.10 =\]

A. 1.15
B. 1.5
C. 2.1
D. 3.35
The graph shows the number of goals scored by 5 players on the soccer team.

<table>
<thead>
<tr>
<th>Soccer Goals Scored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dawn</td>
</tr>
<tr>
<td>Juanita</td>
</tr>
<tr>
<td>Karen</td>
</tr>
<tr>
<td>Sally</td>
</tr>
<tr>
<td>Terri</td>
</tr>
</tbody>
</table>

Each 🏆 means 2 goals scored

43. How many more goals did Karen score than Sally?
   A. 3
   B. 4
   C. 7
   D. 12

44. Which two players scored a total of 12 goals?
   A. Dawn and Karen
   B. Juanita and Sally
   C. Karen and Terri
   D. Terri and Sally
45. Mr. King bought 3 packages of notebook paper for $2 per package. Each package contained 500 sheets of paper. Which method could be used to find the cost of 3 packages of notebook paper?

A. Add 3 and 2 and 500.
B. Add 3 and 2 and subtract the sum from 500.
C. Multiply 3 times 2.
D. Multiply 2 times 500.

46. Tony has read the first 78 pages in a book that is 130 pages long. Which number sentence could be used to find the number of pages Tony must read to finish the book?

A. 130 + 78 = □
B. □ - 78 = 130
C. 130 + 78 = □
D. 130 - 78 = □

47. The Martins are planting a flower garden. They plan to have twice as many tulips as daisies and 4 times as many daisies as violets. What other information could be used to determine the total number of flowers the Martins will plant?

A. The amount of soil for the garden
B. The number of violets they will buy
C. The cost of the flowers
D. The height of each flower
48. The box contains 5 counters. They are the same size and shape but have different patterns.

Which is a possible outcome if 3 counters are selected from the box at one time?

A.  

B.  

C.  

D.  

49. \( 1.4 + 1.1 = \)
50. Sue is making strings of beads for 3 friends. She wants to put 12 beads on each string. Which number sentence could be used to find the number of beads she will need?

A. $12 - 3 = □$
B. $12 \times 3 = □$
C. $12 + 3 = □$
D. $12 ÷ 3 = □$

51. Darren emptied his piggy bank and found the money below. How much money did Darren have in his piggy bank?

A. $1.50  
B. $1.42  
C. $1.24  
D. $1.14
APPENDIX B
A FOURTH GRADE WRITING LESSON:
INVESTIGATING GEOMETRIC TERMS
USING ALPHABET LETTERS
As an introductory activity to writing in mathematics and an introduction to geometry, the researcher taught this lesson to all of the fourth grade students in the treatment group. Because students were familiar with the alphabet, it was a natural resource for engaging students with the language of geometry and for requiring them to use higher level thinking as they compared and contrasted attributes of various letters. In this activity, students were asked to examine the geometric properties of upper case letters, compare letters, and describe their comparisons in writing.

Part 1: Students were introduced to this activity through a class discussion of the attributes of two upper case letters that were written on the board. First, the class described how the two letters were alike, using geometric terms with which they were familiar. After these responses were recorded on the board, the class then described how the two letters were different, as in Figure 1 below.

<table>
<thead>
<tr>
<th>M</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compare</strong></td>
<td><strong>Contrast</strong></td>
</tr>
<tr>
<td>1. Both letters have three acute angles.</td>
<td>1. Only one letter has parallel lines.</td>
</tr>
<tr>
<td>2. They both use only straight lines.</td>
<td>2. Only one letter has a closed region.</td>
</tr>
<tr>
<td>3. They are both symmetrical.</td>
<td>3. One letter has no horizontal lines, but it has a vertical line.</td>
</tr>
<tr>
<td>4. They both have diagonal lines.</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1
Part 2: After the class discussion, students were asked to write down one of their own initials and to make a list of observations about the letter. When finished, students shared their written statements with a partner, adding any other statements to each other's lists that they thought were true. Working with their partners, students created a chart, similar to that in Figure 1, with sentences that told how the letters were alike or different, being careful not to use the letter names in the sentences. When finished, the students gave the teacher their completed charts, from which the teacher selected one or two to play the game described in Part 3.

Part 3: Students played the game, "Guess the Initial," as follows: After selecting one of the completed charts, the teacher wrote on the board only one of the initials. The teacher then began to give clues as to what the other initial might be by reading one sentence at a time from the similarities listed on the chart. As each clue was read, the class eliminated letters in the alphabet that did not share those similarities. After all of the similarities were read, the teacher began to read one by one the list of contrasting attributes. With each clue, the students determined which letters were still possibilities and which could be ruled out. In several cases, more than one letter met all criteria, so the class added clues that helped to narrow the possibilities down to only one letter. After the game was finished, the class discussed which clues were most helpful, noting that the more specific the language was, the easier it was to eliminate incorrect possibilities. Students were encouraged to refine their clues and rewrite any that were incorrect.
APPENDIX C
EXAMPLES OF TRANSACTIONAL, EXPRESSIONS, AND POETIC WRITING-TO-LEARN TASKS IN MATHEMATICS
**Transactional or expository writing tasks** use writing to inform, instruct, or persuade other people. This form of writing is used to convey information through the use of reports, explanations, essays, letters or proposals. It is used for general communication to others. Transactional writing tasks might include the following kinds of prompts:

1. Write a letter to another fourth grader to describe what a fraction is.
2. In your own words, list the steps in problem solving that we use in our math class.
3. Explain what this problem is about, using a drawing, chart, or list to help you.
4. Write the name of the problem solving strategy you used to solve this problem. Exchange your writing with a partner and compare your strategies. Describe one similarity and one difference you see in your methods.
5. Using the information in the chart, write two true statements you can conclude from the data.
6. Explain how you arrived at your prediction. What is another reasonable prediction? Explain why you could have more than one reasonable answer.
7. What new concepts did you learn in class today? What new connections?
8. Justify your answer by explaining why you think it is reasonable.
9. Write another problem for which this same strategy could be used.
10. Give an example of a fraction problem using a set. Give another example of a fraction problem using a circular or rectangular region. Include a drawing.
11. What does it mean to write a fraction in its lowest terms? Give an example.
13. Explain how you know a fraction is in lowest terms. Why would you want a fraction to be in lowest terms?

14. Explain how you organized your information.

**Expressive writing tasks** use writing for reflection, as a tool for discovering meaning and understanding, and to work out ideas and feelings. Expressive writing is usually informal, personal and talky - a written version of thinking out loud. It is used to help students get in touch with themselves and reveals as much about the speaker as it does the topic. Expressive writing tasks might include the following kinds of prompts:

1. How did you feel about your answer?
2. What was the most difficult part of the assignment?
3. What would you have done differently on your graph if you could start over?
4. Write everything that comes to your mind when you hear the word "fraction."
5. What do you think would happen if you multiplied these two fractions instead of added them? Why?
6. What have you learned about fractions that you did not already know?
7. Think of a way you could help a student understand this problem without giving away the answer. What kind of hints help you the best?
8. Was it helpful to work in a group today? Why?
9. Which problems were difficult for you today? Why do you think they were?
10. What made you use that problem solving strategy?
11. What do you feel when someone else’s answer is not the same as yours?
12. Are you comfortable making predictions and estimates? What would help you feel more confident about your predictions and estimates?
13. What is the most helpful suggestion you have given to your group this week? Why?

Poetic writing tasks engage the imagination and serve as an artistic medium for expression. Fiction, poetry, drama, song are examples of this form of writing. Poetic writing tasks might include the following kinds of prompts:

1. Write a poem about geometric shapes.
2. In your group, create a "rap" using a family of multiplication facts.
3. Write a story about something that happened during the last week where you or someone in your family had to use mathematics. Draw a picture to illustrate your story.
4. Describe what your life would be like at school if you were only one-tenth as tall as you are now.
5. Write a fraction story or poem about your family.
6. Write a newspaper headline summarizing the information you collected in your survey.
7. Write a radio ad promoting your method to help other kids master the basic facts. Tell who would need it and why.
8. Make up a new geometry term using the prefixes and suffixes we have learned. Make up a "dictionary-type" definition for it.
9. Design a math slogan to print on the folders that we will hand out at the school's Math Fair.
10. Write a poem about =, +, x, or some other mathematical symbol.
11. Write a math problem to go with this cartoon.
REFERENCES


