Children's Discursive Representations of Their Mathematical Thinking: An Action Research Study

By

Samantha Shyka Amaral

A Thesis

Submitted to the Faculty of Graduate Studies

In Partial Fulfilment of the Requirements of the Degree of

Master of Education

Faculty of Education

Department of Curriculum, Teaching and Learning

University of Manitoba

Winnipeg, Manitoba

THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES

*****

COPYRIGHT PERMISSION PAGE

Children's Discursive Representations of Their Mathematical Thinking:

An Action Research Study

BY

Samantha Shyka Amaral

A Thesis/Practicum submitted to the Faculty of Graduate Studies of the University of Manitoba

in partial fulfilment of the requirements of the degree of

MASTER OF EDUCATION

Table of Contents

Acknowledgements

Phew! I never would have guessed over five years ago that it would have taken me this length of time or this amount of energy to complete my Master of Education degree. Working towards this degree has been with me through many personal milestones, including the first five years of my marriage, the birth of my first child, and my return to work after maternity leave. I was starting to wonder if I would ever finish this thesis. Finally reaching this point feels incredible and suddenly worth all the time and energy.

To my husband, Nelson, thank you for supporting me throughout this journey, encouraging me to continue working, and always having faith that I would complete my Master of Education degree. You are my best friend, an amazing husband, and the best father to our son. I don't think I could have reached this goal without you. Your strength, support, and confidence kept me going, especially during my year of maternity leave when I wanted to work, but just could not seem to do it. I love you!

To Rhys, my little man. - you are the sunshine in my life, you always make me laugh and see the joy in the world. Though you put my schedule to complete this Master of Education degree off by about a year, I wouldn't change a thing. You have taught me to slow down, enjoy the little things, and not stress over the big things. I love seeing the world through your eyes and watching you discover new things everyday. You are a remarkable child, and I look forward to everything that is yet to come. I love you!

To my parents, Henry and Connie Shyka, thank you for your unwavering support that I would complete my Master of Education degree. You have always been there to listen to my rants and problems with the writing of my thesis. I am extremely lucky to have parents who value higher education, and who instilled in me the value of education at an early age. I can honestly say that I have come as far as I have because of your influence, encouragement, and support. I love you both!

To my University Advisor, Dr. Wayne Serebrin, your vast knowledge, enthusiasm for educational concepts, experience, and guidance have been invaluable throughout this journey. I knew I was lucky to have you as my advisor on the first day of my first class with you. Your teaching style and beliefs about children and teaching meshed well with mine and made me excited to be a teacher. You always challenged me to take my thesis research and writing one step further and were always there to encourage me along the way. For that, I cannot thank you enough.

To the other members of my thesis committee, Dr. Francine Morin and Pat Adamson, thank you for making me think about things in ways I had not before. Your questions and suggestions were always very much appreciated. Thank you for taking the time to be a member of my thesis committee.

Last but not least, I would like to thank the students and families of the school I work at. Without you there would be no thesis. Thank you for being on this journey with me. My day-to-day experiences with you are what prompted me to begin the process of obtaining my Master of Education degree, and these same experiences are what allowed me to complete my Master of Education degree. You are the stars of this project, and I know you will continue shining for years to come.

The only thing left to say is "I'M DONE!" Now what on earth will I do with my time?

Abstract

This action research study investigates the effectiveness of math journals, a writing-to-learn in mathematics tool, for improving grade one students' communication of and understanding in mathematics. The relevant literature is comprehensively reviewed. Data collection takes the form of: pre-and post-questionnaires, samples of student math journal entries, teacher-research observations of student writing, and teacher-researcher field notes. The data gathered from four diverse students is selected, analyzed, and discussed. The findings suggest that students' use of math journals can be: an effective means of enhancing learning and communication in mathematics; a way for the teacher to learn more about students' mathematical thinking; and, a vehicle for encouraging written/drawn dialogue between students and the teacher, hence, informing ongoing instruction.

List of Tables

List of Figures

Chapter I: Introduction

There is an old adage that states “people learn best by teaching others”. The concept of writing-to-learn provides students with this opportunity by encouraging them to question and elucidate their own understandings, explain and communicate their thinking, and share their beliefs with others through writing. The purpose of writing-to-learn is not to produce polished pieces of writing that are worthy of publication. Rather, the process of writing is the critical aspect and “is meant to be a catalyst for further learning and meaning making” (Knipper & Duggan, 2006, p. 462). Knipper and Duggan (2006) go on to explain that writing-to-learn is

> an opportunity for students to recall, clarify, and question what they know about a subject and what they still wonder about with regard to that subject matter. Students also discover what they know about their content focus, their language, themselves, and their ability to communicate all of that (pp. 462-463).

Essentially, writing-to-learn provides the opportunity for meaning making and learning through teaching.

This action research study investigates the effectiveness of math journals, a writing-to-learn in mathematics tool, in improving students’ communication in, and understanding of, mathematics. A comprehensive review of the literature, including the theoretical underpinnings and related topics is included. Please see the literature review section of this paper for a literature map detailing the interwoven connections of the topics concerning writing-to-learn in mathematics. The steps taken in the use of math journals are documented through examples of student writing (including pre- and post-

questions to allow for comparison), pre-and-post student questionnaires, teacher-researcher observations of student writing, and teacher-researcher field notes.

Action research was determined to be the best methodology for this study because it is a practice that allows teacher-researchers to learn about and through their own educational practices with the intent of improving their teaching. This methodology engages teacher-researchers in the cycle of "look, think, act" (Stringer, 2008, p. 13), encouraging them to learn about their teaching and their students. Action research is a practice that permits teacher-researchers to explore relevant teaching and learning issues, and reflect on their own teaching practices (Ishii, 2002; Stringer, 2004).

Area of Focus

In the several years that I taught grade one I consistently noticed that the students were not able to clearly communicate their mathematical thinking. Students were often able to produce correct answers in mathematics, but many were entirely unable to communicate their problem solving process. Students who answered mathematical problems incorrectly also had difficulty sharing their thought processes. This proved to be problematic as I was unable to confirm actual understanding and/or determine students' misconceptions. I consistently wondered: "If my students are unable to communicate their mathematical thinking, do they really understand the mathematical content?" This question weighed heavily on my mind when planning instruction. It was difficult to determine what aspect(s) of mathematics to focus on when I was not sure what my students understood.

I have learned from the professional literature that I am not alone in my concern. Young children frequently have difficulty explaining the mathematical processes they use

to answer questions (Anderson & Little, 2004) and the language of mathematics often comes across like a foreign language (Bechervaise, 1992). Mathematics has a specific vocabulary that students must clearly understand in order for them to comprehend mathematical concepts (Blessman & Myszczak, 2001). Additionally, students often see mathematics as a subject with one right answer and formulas that require memorization. Working with this misconception, mathematics often becomes a rote skill, not something that is genuinely understood (Borasi & Rosi, 1989).

The issue of communication in mathematics is one of increasing concern in education. To assist in the awareness of the issue, and to offer assistance in "solving" the problem, the National Council of Teachers of Mathematics (NCTM) issued a document in 2000 entitled *Principles and Standards for School Mathematics*. In this document an entire standard is devoted to increasing student mathematical communication. The NCTM document suggests that students learn to communicate mathematically through talking, writing (representing), and reading. The document states that "[c]ommunication is an essential part of mathematics and mathematics education" (p. 60).

The Western and Northern Canadian Protocol (WNCP) provides a conceptual framework upon which the new Manitoba mathematics curriculum is based. The WNCP (2006) document includes communication as one of seven essential skills for students explaining that "[s]tudents must be able to communicate mathematical ideas in a variety of ways and contexts" (p. 6). The WNCP document asserts that students require opportunities to "read about, represent, view, write about, listen to and discuss mathematical ideas" (p. 6) and that through these opportunities, students will build

connections between their own language and thoughts, and the content area of mathematics. The WNCP framework goes on to explain that communication is crucial in "clarifying, reinforcing and modifying ideas, attitudes and beliefs about mathematics" (p. 6).

Research Questions

My personal experiences along with the increased curricular focus on communication in mathematics in education have helped me realize that a clear link between language and mathematics had to exist in my classroom and day-to-day teaching. I chose to focus my attention on writing-to-learn in mathematics because some educators believe that "to engage students in writing activities about content is to engage students in learning that content" (Bangert-Drowns, Hurley & Wilkinson, 2004, p. 30). Bangert-Drowns and colleagues go on to explain that several prominent scholars believe that writing is the concrete manifestation of thinking and learning and, therefore, "to write is to learn" (p. 32). Frank Smith (1986) reiterates this point by stating "we find out what we think when we write, and in the process we put thinking to work" (p. 35). These ideas relate to the concept of metacognition and encouraging students to think about their thinking. Huggins and Maiste (1999) believe that writing enables students to think metacognitively and clarify their understandings. They understand that writing-to-learn in mathematics encourages students to become active participants in their own learning and to transfer their thoughts to written form that promotes processing and the building of connections between present knowledge and future knowledge. Taking all of this into consideration has led me to develop the following four research questions, which I will investigate throughout the course of this action research study:

1. How can I gain further insights into my students' mathematical thinking?
2. Can writing-to-learn in mathematics, in the form of math journals, improve students' communication in mathematics?
3. Can writing-to-learn in mathematics, in the form of math journals, improve students' learning in mathematics?
4. How will reading and responding to students' writing in math journals influence my teaching?

Chapter II: Literature Review

There is a growing body of literature which conceptually grounds this action research study. The areas of pragmatism, social constructivism, and metacognition provide the theoretical underpinnings for writing-to-learn in mathematics. These areas provide the research background for consideration of the roles of dialogue, attitudes, reflection, and understanding of mathematics. Dialogue, attitudes, reflection, and understanding are all critical aspects for the development of students' discursive representations of their mathematical thinking and must be clearly understood in relation to this action research study. Figure 1 is a literature map showing the connections that exist between the different areas related to writing-to-learn in mathematics and this thesis. This map may help to clarify the relationships that are present and make the following literature review easier to understand. Alternatively, one might chose to look at, and/or return to, this literature map after reading the written background, as a way of symbolically viewing the connections between the different areas related to writing-to-learn in mathematics that are discussed in the literature review.

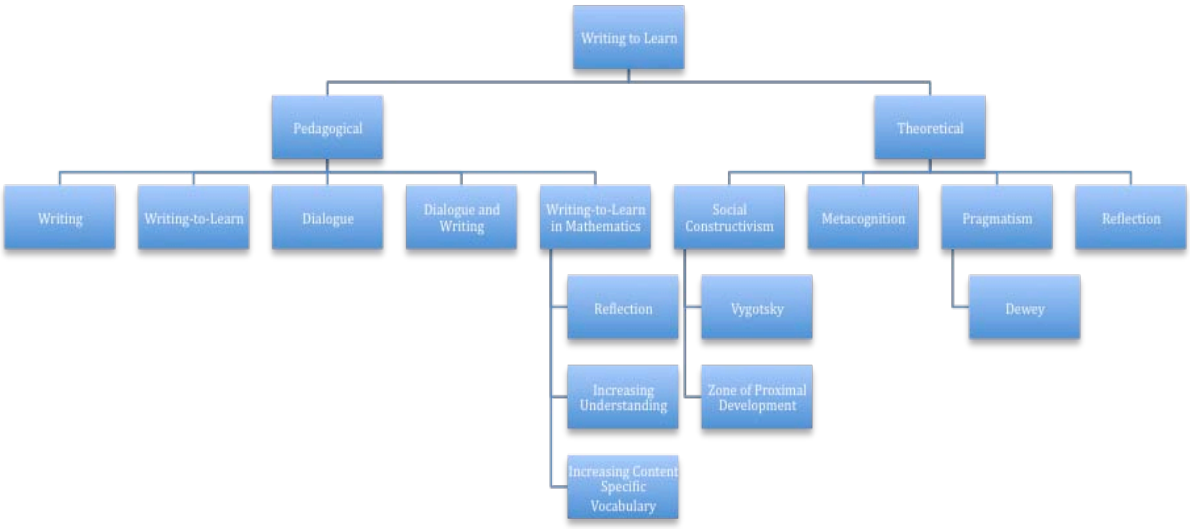


Figure 1. Literature Map

Writing

Frank Smith (1982) asserts that writing can contribute to all aspects of our lives. It is an extension and reflection of all that we do. Writing helps us to enforce order upon the world, to understand the happenings around us, and to express ourselves to the world. Writing in general "can be expected to enhance learning in academic settings" (Bangert-Drowns et al, 2004, p. 53). Writing demands active participation on the part of the student (Azzolino, 1990). Both Azzolino and Fortescue (1994) indicate that all types of writing require students to synthesize and organize their ideas in a way that makes sense to them and to their potential readers; therefore, writing builds understanding. Azzolino expands upon this, stating that writing provides students with the opportunity to define, discuss, or describe ideas and/or concepts. Smith reiterates this point with the powerful quote "[b]y writing what I think I know, I develop what I potentially knew. Writing does

more than reflect underlying thought, it liberates and develops it" (p. 33). LeGere (1991) agrees, stating that "[w]henever students are asked to write, they are really being asked to think. Writing requires an involvement, a shaping of thought, a commitment. It produces a product that allows the writer to review, revise, and shape anew" (p. 170). Building on this concept Jurdak and Zein (1998) state that "writing can engage all students actively in the deliberate structuring of meaning, it allows learners to learn at their own pace, and it provides immediate feedback by enabling learners to read the product of their thinking on paper" (p. 412). McCallum and Whitlow (1994) believe that writing and representations are a necessary aspect of ongoing instruction.

Writing-to-Learn

"Writing to learn a content area is different than writing across the curriculum" (Miller & England, 1989). The purpose of writing across the curriculum is to improve student writing. The objective behind writing-to-learn in a content area is to concentrate students' thinking toward a clearer, more in-depth understanding of the subject area (Miller & England). Writing-to-learn involves students discovering new ideas and/or internalizing knowledge by writing about their understandings and feelings. Writing-to-learn integrates the English Language Arts of speaking (including internal dialogue), reading, writing, viewing, and representing with content area subject matter. Writing-to-learn "can support more sophisticated elaboration and organizational strategies by linking new understandings with familiar ones, synthesizing knowledge, exploring relations and implications, and building outlines and conceptual frameworks. And writing can be a tool of self-reflective monitoring of comprehension, thus creating opportunities for students to evaluate their own understandings, confusions, and feelings about a topic" (Bangert-

Drowns et al, 2004, p. 32). Writing to learn can help students to review, refocus, and reconsider learned topics (Azzolino, 1990). Hanson (2001) highlights the importance of writing-to-learn by stating, "[w]riting across the curriculum enlarges students' worlds. They see details they might otherwise not notice, [and] become skilled at writing techniques they may otherwise never use" (p. 102). Emig (1977) supports this idea by noting that writing-to-learn in the content areas encourages students to compare facts, analyze, and synthesize content specific material. Fortescue (1994) adds to this by stating that writing-to-learn in the content areas increases understanding of the content area. LeGere (1991) concurs, asserting that students who participate in writing-to-learn retain concepts and learn better. Schwarz (1999) expands this understanding by explaining that writing-to-learn requires students to focus on the topic at hand, internalize the critical components, and describe their knowledge in their own words. Therefore, writing-to-learn fosters increased understanding and academic achievement.

Not all writing qualifies as writing-to-learn. Writing-to-learn is not a listing of facts or ideas gained through direct teaching experiences and recorded by passive students. Rather, writing-to-learn is a specific form of writing that requires students to be actively involved in activities and processes that build connections between what they are studying and their current knowledge base (Borasi & Rose, 1989). In writing-to-learn it is not the written product that matters, but the process of writing (Knipper & Duggan, 2006; McIntosh & Draper, 2001). Maxwell (1996) highlights this by stating "we write to think and think to write; therefore, much of our writing is putting thoughts on paper, not final drafts" (p. 84). Bangert-Drowns et al. (2004) found that writing-to-learn activities that ask students to reflect upon current understandings, learning processes, and confusions

tended to be the most positive. Writing-to-learn can help students make new discoveries, about which they gain knowledge as they write (Borasi & Rose). Pearce and Davison (1988) highlight the concepts behind writing-to-learn by stating that higher level thinking activities that compel students to create clear, original pieces of writing are an extraordinarily valuable way to support students' learning because "original writing requires active thought" (p. 7).

McIntosh (1991) indicates that writing-to-learn can also open the lines of communication between students and teachers. Graves (1983) believes that dialogue journals, a form of writing-to-learn where students and teachers converse in writing, are one way to foster this open communication. Staton (1980) describes dialogue journals as a means for students to privately share their thinking, understandings, misconceptions, difficulties, questions, and concerns with their teacher – a place where the teacher can respond in writing to the students. Writing for the sake of communication is of utmost importance because it provides students with a record of their thinking and idea development (Phillips & Crespo, 1995). Writing-to-learn presents students with the occasion to make their thinking visible. This offers teachers the chance to peek through a "window" into student thinking (Whitin & Whitin, 2000). Reading pieces that students produce while writing-to-learn provides teachers with the opportunity to identify student misconceptions and problems and improve their teaching (Azzolino, 1990).

Dialogue

Talk, conversation, discourse, speech and dialogue are all terms that are used to represent students use of oral language to learn and understand in academic environments. McCallum and Whitlow (1994) state that "putting concepts into words is

the cornerstone of learning" (p. 25). Halliday (2004) asserts that conversations between students "evolve as the joint construct of shared experience, whereby phenomena that are accessible to the consciousness of both parties – things both can see, events both have experienced – are turned dialogically into meanings" (p. 139). The National Council of Teachers of Mathematics (NCTM, 1989) reiterates this point by stating that young children are very social and much of the sense they infer from the world comes from their communications with others. The NCTM expresses the belief that "children learn from one another as they communicate" (p. 28) and that "communicating helps children to clarify their thinking and sharpen their understandings" (p. 26). Huinker and Laughlin (1996) state that "dialogue enables students to talk their way to meaning" (p. 81). Halliday (2004) goes on to explain that "from the ontogenesis of conversation we can gain insight into human learning and human understanding" (p. 143). Thus, it is easy to see how dialogue influences knowledge and understandings.

Listening to the communication between students or between a student and teacher provides information about student thinking and understanding, "a rich information base from which [teachers] can make sound instructional decisions" (National Council of Teachers of Mathematics, 1989, p. 28). Conversations with students can demonstrate areas of misunderstanding, which educators can address with individuals, in small groups, or with the whole class. Teachers must value students "language, questions, descriptions, observations, and stories because they are windows into the process of how our students construct meaning" (National Council of Teachers of Mathematics, p. 2).

Dialogue and Writing

Gee (2004) argues that "reading and writing cannot be separated from speaking, listening, and interacting, on the one hand, or using language to think about and act on the world, on the other" (p. 116). Therefore, we can infer that written communication is a language process that cannot exist without dialogue. In order to learn to communicate in a written format we move from social dialogue, to self dialogue, to writing. Dyson (2004) illustrates this understanding by stating that even though adults and older children often write silently, young children are characteristically audible writers, as they are still developing their capacity for inner speech (Vygotsky, 1962). Children gather and organize their ideas through talking with others. This generating of ideas helps young children to sustain their written voices (Dyson, 2004). Huinker and Laughlin (1996) reiterate this point by explaining that "thinking and talking are important steps in the process of bringing meaning into students' writing" (p. 81) and as students talk about their ideas in relation to personal experiences they become capable of writing about these ideas and understandings. Huinker and Laughlin clarify this point by stating that "when students are given numerous opportunities to talk, the meaning that is constructed finds its way into students' writing, and the writing further contributes to the construction of meaning" (p. 88). Layzer (1989) states that conversing and writing about mathematics motivates the efforts needed to master abstract concepts in the subject area. Conversely, as students deepen their understandings of abstract mathematical concepts they are better able to write and dialogue about these concepts. Simply stated, students do not understand mathematical content and/or concepts until they converse and write about it

(McCallum & Whitlow, 1994). Bechervaise (1992) summarizes this notion by stating that "language is central to the teaching of mathematics" (p. 4).

Theoretical Foundations for Writing-to-Learn

Social constructivism and Vygotsky. Social constructivism is the theoretical foundation for writing-to-learn. From a social constructivist perspective knowledge is understood to be co-created during social interaction (Palincsar, 1998). Vygotsky (1978) whose ideas are representative of a social constructivist perspective, believed that social interaction had a deep influence on cognitive development. Vygotsky also believed that development was an ongoing process, from birth to death, not a product of process through distinct stages (Driscoll, 1994), as described by cognitivists such as Piaget. The focus of Vygotskian social constructivism "is on the connections between people and the cultural context in which they act and interact in shared experiences and communication aimed at inter-subjectivity – a shared consciousness of culturally significant phenomena mediated by the use of language and other symbolic tools" (Crawford, 1996, p. 44).

Vygotsky's social development theory states that life-long development is dependent upon social interaction, and that this social interaction leads to cognitive development. A significant piece of Vygotsky's theory, in relation to education, is the Zone of Proximal Development. Vygotsky describes the Zone of Proximal Development as "the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (Vygotsky, 1978, p. 89). Therefore, in the Zone of Proximal Development a student can achieve academic success with the assistance of an adult or knowledgeable peer that he/she could

not have accomplished independently. Vygotsky states that learning occurs in this Zone of Proximal Development and it "bridges the gap between what is known and what can be known" (Riddle, 1999, p. 1).

Essential to Vygotsky's social development theory of learning was his conviction that biological and cultural development did not occur in isolation. He studied the connections among people, their cultural context, and their shared experiences (Crawford, 1996). Vygotsky recognized the social nature of how learners construct knowledge and encouraged the expression of understanding through the use of tools, such as writing, talking, drawing, and building models (Whitin & Whitin, 2000). He believed that young children first develop these tools to communicate their needs in a social manner, but then begin to internalize these tools, which leads to higher level thinking as they mature (Riddle, 1999). Vygotskian theory states that "as members of a collaborative learning community the children are learning that together they can go further than any of them could go alone" (Whitin & Whitin, 2000, p. 3). Thus, Vygotsky believed that thought and language could not exist without each other (Riddle,1999).

The understanding that thought and language are intimately connected has implications for classroom teachers. Vygotsky's belief encourages teachers to collaborate with students, assist students in developing meaning in their own ways, and engage in reciprocal teaching (Riddle, 1998). Vygotsky (1978) recognizes that using language in exploratory ways allows students to develop an increased sense of their own learning and understanding. Activities in which students write-to-learn reinforce Vygotsky's beliefs and put the theory into practice. Vygotsky posited that writing was a means through which students could share their thinking and reasoning with their teachers, and

demonstrate their understandings and/or lack of understandings. Today we could call this type of writing “writing-to-learn”. Vygotsky understood that writing required analytical thinking on the part of the author. To write, one has to synthesize, make connections to prior knowledge, and make the writing content understandable. In essence, writing is a form of metacognition.

Metacognition. Writing-to-learn encourages students to reflect on their learning, knowledge, and feelings; it promotes, and helps students to develop metacognitive thinking (Bangert-Drowns et al, 2004; Brewster, & Klump, 2004; LeGere, 1991; Pugalee, 1997). Metacognition is awareness and self-regulation of your own thinking and cognitive processes. It is thinking about one’s thinking. It involves predicting, outlining, revising, deciding, checking, speculating, sorting, and naming - behaviours that are all used in writing-to-learn. Metacognition is essential to successful learning, and writing-to-learn provides the opportunities necessary to promote metacognitive behaviours (Pugalee, 2001).

Pragmatism. John Dewey, considered to be one of the founders of pragmatism, “adopts what in current terminology would be termed as a social constructivist view of teaching and learning” (Prawat, 2000, p. 808). Pragmatism is a philosophy that views knowledge as an instrument or tool for organizing experience, and is concerned with the union of theory and practice. A pragmatic philosophical view of learning that Dewey called the “constructive process of knowing”, regards learning as constructing or appropriating new meaning out of an experience. Dewey acknowledged that all forms of language influence knowledge and experience, and vice versa. According to Deweyan pragmatism, writing allows educators to “teach our students to be the agents of ideas

without ever letting them imagine they are the sole authors of these thoughts" (Jones, 1996, p. 3). This is the basis for writing-to-learn. When writing-to-learn students are encountering and internalizing ideas that may be new discoveries to them. They are moving between what pragmatics called subjective and objective knowledge (Prawat, 2000) through writing-to-learn. Janet Emig agreed with this idea stating back in the 1970s that John Dewey greatly influenced the concepts of writing in education (Jones, 1996).

Reflection. John Dewey was also a firm believer in the power of reflection - the "thinking through of possible courses of action" (Willower, 1992, p. 3). Dewey believed that reflection needed to become a habit and that reflection allowed for personal growth (Willower, 1992). Writing-to-learn promotes ongoing reflection among students. It allows students to reflect on their understandings and process their knowledge, which leads to increased comprehension of the content (Blessman & Myszczak, 2001; Ishii, 2002).

Writing-to-Learn in Mathematics

According to the National Council of Teachers of Mathematics: "writing is a communication skill that has been used too infrequently in mathematics" (NCTM, 1989, p. 28). Writing-to-learn in a mathematics classroom is a way of assisting teachers in remedying this situation. Writing-to-learn in mathematics provides "a valuable means to facilitate a personalized and making-of-meaning approach to learning mathematics" (Borasi & Rose, 1989, p. 347). Miller (1991) explains that "[t]he construction of knowledge requires active engagement in thought-provoking activities. Because writing leads people to think, improved mastery of mathematics concepts and skills is possible if students are asked to write about their understandings" (p. 517). Azzolino (1990) agrees

stating that writing-to-learn in mathematics can encourage students to personalize, assimilate, and accommodate the mathematics concepts addressed in class. It can also assist students in recording mathematical understandings for future reference and retain mathematical procedures and algorithms. Pengelly (1990) goes on to state that through writing-to-learn in mathematics, students' mathematical thinking "becomes more sophisticated and complex as ideas are generalized and abstracted" (p. 13).

Writing is an excellent way to begin a mathematic class (Azzolino, 1990). A prompt can actively engage students in a topic relevant to the day's lesson, which encourages students to activate their prior knowledge and begin thinking about the mathematical concept (Miller, 1992). Writing-to-learn in mathematics requires students to think about a topic, focus on important concepts, and make those concepts their own (Hackett & Wilson, 1995). Writing-to-learn in mathematics provides students with the opportunity to extend and clarify their existing knowledge and "can cause students to analyze, compare facts, and synthesize relevant material" (Schwarz, 1999, p. 28). Writing-to-learn in mathematics elucidates student thinking and helps to develop deeper student understanding (National Council of Teachers of Mathematics, 1989).

Writing-to-learn in mathematics includes writing as well as representing, that is drawing pictures to explain thinking (Wilde, 1991). Writing-to-learn in mathematics is also effective when following hands-on activities (Wilde), thus bridging the gap between the concrete and the abstract. Having students participate in writing-to-learn in mathematics at the end of class provides students with the opportunity to summarize the mathematical idea(s) shared in the lesson for themselves (Azzolino, 1990) and further solidify their learning.

Haggerty and Wolf (1991) suggest that writing-to-learn in the mathematics classroom can take a variety of forms, such as: writing how-to descriptions, defining vocabulary, creating riddles, summarizing, correcting problems, and providing and getting feedback from other students. Haggerty and Wolf also include guidelines for student writing-to-learn in mathematics. These guidelines include the idea that students should write-to-learn in the subject area daily. They also suggest that teachers should write with the students, share their writing with their students, and make their students feel good about their writing.

Nahrgang and Petersen (1986) state that "the most effective method of using writing to help students learn mathematics is through the use of journals" (p. 461). Math journals, a form of dialogue journal, engage students in writing-to-learn in mathematics and can extend students' understanding, communication, and language and literacy across curricular areas. Jouranls are an informal type of writing designed to facilitate open communication between a student and teacher (Hackett & Wilson, 1995; National Council of Teachers of Mathematics, 1989; Schwarz, 1999). Math journals provide students with the opportunity to communicate privately and in a relaxed format with their teacher (McCallum & Whitlow, 1994).

Nahrgang and Petersen (1986) indicate two functions of math journals. First, they allow students to work at their own rate and to understand mathematical topics and concepts in relation to their own experiences. Math journals facilitate understanding in mathematics because they support the students in collecting, internalizing, synthesizing, and evaluating knowledge. Secondly, math journals are a method of assessment for learning. They can reveal difficulties that students have with the topics and concepts at

hand. Math journals are diagnostic tools that assist teachers in identifying areas of difficulty, confusion, and misunderstanding. Nahrgang and Petersen go on to explain that math journals are a series of assignments (writing entries) that respond to a teacher's question, statement, or prompt. Students can also contribute open-ended responses in their math journals. Cai, Jakabesin, and Lane (1996), proponents of open-ended responses in mathematics, state that when responding in open-ended tasks, students are required to justify their answers. In justifying their answers, students showcase their mathematical thinking, understanding, reasoning, and problem-solving. Cai, Jakabesin, and Lane also state that teachers need to create instruction activities that use open-ended tasks as this will assist students in internalizing the mathematical concepts and promote increased student proficiency in mathematics.

Math journals do not necessarily produce finished, polished products (Wilde, 1991). It is the process of writing and thinking that is important, not the product (Gordan & MacInnis, 1993; Graves, 1983). The objective of writing in math journals is writing-to-learn in mathematics, not learning to write. Therefore, spelling, grammar, and conventions are not the primary focus (Azzolino, 1990; Miller, 1991; Miller, 1992).

Adding math journals to regular mathematics classes does not take time away from instruction. Rather, math journals improve instruction because the teacher gathers insights into what to work on next, from reading the students' writing as misconceptions and gaps in understanding are exposed (MacGregor, 1990). Additionally, during writing time the students are writing about mathematical content, thereby, internalizing the knowledge (McIntosh & Draper, 2001). Writing-to-learn in mathematics provides students with opportunities to find out what they think while they write, reflect, and

clarify their thinking (Miller, 1992). Huinker and Laughlin (1996) indicate that teachers will see improvements in students' writing, and hear more in-depth conversations among students when the learners participate in writing-to-learn in mathematics. MacGregor believes that writing-to-learn in mathematics is a valuable learning technique that deserves attention from both educators and researchers. MacGregor takes this concept one step further, indicating that teachers must take responsibility and teach the students how to write-to-learn in mathematics in order for writing-to-learn in mathematics to be the most effective.

A thorough review of the literature on writing-to-learn in mathematics has uncovered several key findings. Math journals facilitate one-on-one, teacher-to-student communication (Gordan & MacInnis, 1993; Jurdak & Zein, 1998; 1993; Miller, 1991). They provide a realistic manner for a teacher to listen and "talk" to each student individually and on a regular basis (Gordan & MacInnis). Writing-to-learn in mathematics also provides the opportunity for students who are not comfortable talking in front of their peers to "speak" to the teacher in a direct, yet private, manner in a nonthreatening environment (Gordan & MacInnis; Koirala, 2002; Miller; Miller, 1992; Phillips & Crespo, 1995; Schwarz, 1999). Writing-to-learn in mathematics has a positive effect on students' attitudes, self-confidence, and motivation towards their learning in mathematics and reduces anxiety towards the subject area (Anderson & Little, 2004; Blessman & Myszczak, 2001; Borasi & Rose, 1989; Hackett & Wilson, 1995; Huggins & Maiste, 1999; Ishii, 2002; Schwarz, 1999). Writing-to-learn in mathematics can also serve as a place for students to express their emotional responses to their learning. It can be a place for students to share their frustrations and lack of understanding in

mathematics (Borasi & Rose; Chapman, 1996; Gordan & MacInnis). Borasi and Rose explain that by stating these feelings and frustrations students become more aware of them and become more open to changing them. Additionally, though this was not a primary goal of any of the reviewed research, some studies found that writing-to-learn in mathematics also improved student writing in other subject areas (Anderson & Little; Borasi & Rose).

A key finding in the research on writing-to-learn in mathematics indicates that math journals create an ongoing written dialogue in the classroom from which both students and teachers benefit (Borasi & Rose, 1989; Ishii, 2002). Borasi and Rose continue this idea, stating:

> [b]y writing in the journals, students make use of *writing* as a learning tool in the context of mathematics; by reading students' journals, teachers access a wealth of information usually unavailable to them; and by commenting on students' entries, responding to specific questions and posing new ones, teachers engage in a unique and continuous dialogue with each individual student (p. 362).

When writing in math journals, students are encouraged to explain their thought processes in their own way and communicate this to their teacher. In order for math journals to be an effective means of creating dialogue between student and teacher, teachers must read all journal entries and respond in a non-graded, supportive manner (Borasi & Rose, 1989; Gordan & MacInnis, 1993; McIntosh, 1991). Math journals are also a good place for teachers to provide precise encouragement through their responses (McIntosh). Borasi and Rose found that students began to take more risks once they knew

they had their teacher's support. They also found that writing in math journals built mutual trust between the students and their teacher. Gordan and MacInnis (1993) found that through dialogue with math journals students felt comfortable sharing their confusions and difficulties and providing teachers with instructional suggestions that they believed would assist in their learning. Math journals open the lines of communication between the students and teacher and facilitate a positive classroom environment (Miller, 1992). Moreover, students often enjoy writing in their math journals (Gordan & MacInnis; Huggins & Maiste, 1999; Koirala, 2002).

A further key finding indicates that writing-to-learn in mathematics is an effective means of increasing student communication in mathematics. This enhanced communication arises as students construct knowledge together through shared experiences and conversations. Many researchers also found that writing in mathematics was a means for individual students to reflect upon their understandings and beliefs, ask questions, explore concepts, express feelings, and anxieties (Blessman & Myszczak, 2001; Borasi & Rose, 1989; Chapman, 1996; Gordan & MacInnis, 1993; Hackett & Wilson, 1995; Huggins & Maiste, 1999; Ishii, 2002; Jurdak & Zein, 1998; McIntosh, 1991; Nahrgang & Petersen, 1986). Math journals encourage students to write what they are thinking and feeling; thereby, communicating their mathematical thinking. Without this opportunity, students may not consider these thoughts and/or feelings and the newfound awareness that results from communicating their mathematical thinking in writing can increase academic achievement and promote further reflection. Chapman explains that math journals reveal students' thinking processes. Writing-to-learn helps students to communicate where they are having difficulty and where they are capable.

Written reflections provide a record of mathematical learning, help the students to process their knowledge, and lead to an increased comprehension of the content, which is another key finding (Blessman & Myszczak; Borasi & Rose; Jurdak & Zein).

As indicated above, writing-to-learn in mathematics is an effective way of increasing students' understanding of, and vocabulary in, mathematical concepts (Bangert-Drowns et al, 2004; Blessman & Myszczak, 2001; Borasi & Rose, 1989; Fortescue, 1994; Gordan & MacInnis, 1993; Hackett & Wilson, 1995; Ishii, 2002; Jurdak & Zein, 1998; Koirala, 2002; LeGere, 1991; McIntosh, 1991; Miller, 1991; Schwarz, 1999; Wilde, 1991). Krussel (1998) states that students need to learn the language and vocabulary of mathematics; if they do not they can not communicate effectively in the subject area. Schwarz reiterates this concept by stating that "it is crucial to emphasize vocabulary instruction as part of a mathematics program" (p. 16). Math journals provide students with the opportunity to learn, practice, and communicate using content specific language and vocabulary. Borasi and Rose (1989) state that writing in math journals contributes to the learning process because all students are engaged in the activity simultaneously, students learn at their own pace, and there is consistent feedback. Additionally, researchers believe that restating an understanding of concepts in your own words can internalize this understanding, thus prompting increased learning (Borasi & Rose; Ishii, 2002).

The reviewed research suggests that writing-to-learn in mathematics can also benefit teachers. It is an assessment *for* learning tool (Manitoba Education Citizenship and Youth, 2006) that can provide information on student understanding, misconceptions, and feelings, and help drive instruction (Borasi & Rose, 1989; Gordan & MacInnis, 1993;

Hackett & Wilson, 1995; Huggins & Maiste, 1999; Ishii, 2002; Koirala, 2002; LeGere, 1991; MacGregor, 1990; McCallum & Whitlow, 1994; McIntosh, 1991; McIntosh & Draper, 2001; Miller, 1991; Miller, 1992; Phillips & Crespo, 1995; Pugalee, 1997; Pugalee, 2001; Schwarz, 1999; Wilde, 1991). Math journals provide opportunities for teachers to get to know their students more on an individual and personal level and develop individualized/differentiated instruction based on individual students' needs. Miller (1991) indicates that "[r]eading students' writing may help you teach better" (p. 518). Based on information gathered from math journal entries teachers can clear up student misconceptions individually or as a whole class, and assist students in developing clear understandings before they get discouraged and/or frustrated. Math journals provide a record of student development and growth. They provide a window into students' thinking (McIntosh). In addition to being an assessment *for* learning tool, Blessman and Myszczak (2001) indicate that writing in mathematics is an authentic assessment *of* learning tool in that it allows for a demonstration of student knowledge of the taught material. Hackett and Wilson (1995) concur, stating that "if students can write clearly about mathematical ideas, then it is clear that they understand those ideas" (p. 7).

Borasi and Rose (1989) believe that teachers should provide students with a rationale for writing-to-learn in mathematics that includes the opportunity to: reflect upon feelings about mathematics; share understandings and lack of understandings; provide the teacher with insight; and, engage in an ongoing dialogue with the teacher. McIntosh and Draper (2001) provide the following guiding statements for the successful implementation of writing-to-learn in mathematics:

1. Have the students complete writing in mathematics several times a week. This encourages the students to think about mathematics and communicate their thinking on a frequent basis.
2. There may be mild resistance at first, just keep at it and as the students begin to see the benefits they will enjoy writing more.
3. Teachers should write when the students are writing.
4. Teachers should expect full answers. A lack of understanding is fine, but a lack of effort is not acceptable.
5. Students must be aware of the fact that their writing will be read and responded to.
6. Teachers must respond positively to students' mathematical writing.

Chapter III: Research Design

This section will provided a detailed account of the research design for my study. Included will be discussions on my action plan, data collection, ethical issues, data analysis, and research quality.

Action Plan

Drawing on the ideas gathered through the literature review, I implemented math journals in my grade one class of twenty-five students; nineteen of whom provided consent to be involved in this study. Nahrgang and Petersen (1986) indicate that math journals are the most effective method of writing-to-learn in mathematics. The math journals took the form of a dialogue journal (Staton, 1980) in which the students responded to different questions, statements, or prompts and had the chance to write open-ended responses as well (Nahrgang & Petersen).

In their math journals the students had the opportunity to use writing and representation (drawing) to convey their message and explain their thinking (Wilde, 1991). They had a choice of three different writing papers to choose from (Appendix 1), which facilitated the options of writing and/or representing. It was my hope going into this study that the math journals would facilitate open communication between my students and me, and encourage ongoing dialogue (Gordan & MacInnis, 1993; Hackett & Wilson, 1995; Miller, 1991; Miller, 1992; Schwarz, 1999). To reinforce the written dialogue in the math journals I read all students' entries and replied to them in a positive, non-threatening, encouraging, and timely manner. I responded to student questions and posed new questions for them (Borasi & Rose, 1989; Gordan & MacInnis; McIntosh, 1991). Additionally, as indicated in the literature review (Gordan & MacInnis; Graves,

1983; Miller, 1991; Miller, 1992; Wilde) I was not looking for a final, polished writing entry in each math journal entry. The important aspect of writing-to-learn in mathematics is the thinking process, not the presentation of the writing. I did not mark the journal for spelling, grammar, and/or conventions. I used the writing of math journal entries as a writing-to-learn activity.

My research took place during a unit of study on equality, where the students participated in active, hands-on learning and responded to their learning in their math journals on a regular basis. Wilde (1991) indicates that writing-to-learn in mathematics is most effective when following hands-on activities. McIntosh and Draper (2001) suggest that it is best to have students write in their math journals several times per week. Therefore, the students were provided with time to write in their math journals three times per six-day cycle for seven cycles. This resulted in eighteen math journal entries per student since there were a few in-service days during the implementation period of this study, when writing in math journals did not take place.

Data Collection

Data collection took the form of student pre- and post-questionnaires, student writing samples, anecdotal teacher-researcher observations (of students/participants), and researcher field notes/reflections (including lesson planning). These four types of data collection were sufficient to allow me to apply the principle of triangulation, since there is at least one type of data collection from each of the three forms of qualitative data: interviews (the questionnaires), observations (anecdotal teacher-research observations and researcher field notes), and documents/artifacts (student writing samples). These multiple data sources assist in making the study more credible and trustworthy

(Stringer, 2004). The way in which my data sources align with my research questions is shown in Table 1.

Table 1

Data Matrix

	Student Pre- and Post-Questionnaires	Student Pre- and Post-Writing Samples (3 questions)	Student Writing Samples	Teacher-Researcher Observations	Researcher Field Notes/Lesson Plans and Reflections
1. How can I gain further insights into my students' mathematical thinking?	x		x	x	
2. Can writing-to-learn in mathematics, in the form of math journals, improve students' communication in mathematics?	x	x	x	x	
3. Can writing-to-learn in mathematics, in the form of math journals, improve students' learning in mathematics?	x	x	x	x	
4. How will reading and responding to students' writing in math journals influence my teaching.				x	x

Prior to the start of the study, the students completed the first questionnaire (Appendix 2). This questionnaire provided me with the students' perspectives on their thinking, feelings, and understandings towards mathematics, specifically, with respect to equality, which was the concept addressed during the study. At the conclusion of the

study, students completed the second questionnaire (Appendix 3) addressing the same issues, as well as asking for the students' reflections about writing in their math journals.

Student writing samples from their math journals were the second source of data collection in my study. I hoped that the students' math journal entries would help me to gain further insight into the students' mathematical thinking and understanding and provide me with assessment *for* learning of concepts and processes I could use to drive instruction, while also showing evidence of student mathematical communication. Each participant had the opportunity to write eighteen math journal entries during the course of this study, though some students may have been absent at times, potentially resulting in less than eighteen entries. The journal writing included three pre- and three post-pieces of writing (which allowed for comparisons) that addressed the following questions: "What is equality?"; "What is inequality?"; and, "What does this symbol (=) mean?"

The final two sources of data collected were anecdotal teacher-researcher observations and researcher field notes. I made observations of students' mathematical communication, body language, comments about their attitudes, and understandings during the time students were engaged in writing in their math journals over the duration of the study. Additionally, I kept teacher-researcher field notes on a regular basis which recorded my personal feelings, questions, and reflections about the study in general.

Ethical Issues

I was the teacher and the researcher for this study, and the participants were my grade one students. Because of this relationship, the main ethical dilemma I faced was one of power. I was in a position of power over my students. This relationship had the potential to influence student behaviour, student participation in the study, and

parental/guardian consent concerning whether or not their child would participate in the study. It was possible that my students may have attempted to please me by doing/producing what they thought I wanted to see and hear rather than behaving "normally" during the study. Additionally, the students and their parents/guardians may have felt pressure to participate in the study because I was the teacher.

To help alleviate these issues and concerns, a detailed consent form (Appendix 4) containing all relevant details was sent home with all of the students in my class prior to the beginning of the study. The consent form notified the parents/guardians of all the details of the action research project. The consent form indicated that participation was not required, and that I was not to be aware of who was participating in the study until the 2007 – 2008 school year concluded on June 27, 2008. By reading the consent form, the parents/guardians learned that all students would be participating in writing-to-learn in mathematics through math journals, because I believed it was a valuable teaching and learning tool, regardless of whether or not they were participants in the action research study. The consent form explained that all that was expected of the study participants was their regular behaviour and work ethic. They would not be harmed in any way as a result of participating in this action research study. The consent form indicated that there was no negative consequence should a student choose not to participate in the formal research study, and it explained that they could withdraw from the study at any time by contacting the school secretary. To ensure that I was unaware of who was participating in the study, the school secretary confidentially collected and kept the consent forms until the conclusion of the 2007 – 2008 school year, at which time my power-over relationship with the students - as students with me as their classroom teacher - no longer existed. The

consent form also indicated which university authorities parents/guardians could contact with any questions and/or concerns. A script for parents to assist them in discussing the action research project with their child was attached to the consent form. Through the consent form, parents/guardians were informed that if they chose to allow their child to participate in this action research project, the child's confidentiality would be ensured, and pseudonyms would be used in the writing of my thesis. If consent was granted, the parents/guardians and student signed, dated, and returned one copy of the consent form to the secretary, and kept the other copy for their records.

Duty of care was another ethical issue that I needed to keep in mind throughout this study. I needed to ensure that all information was safely secured. Additionally, I was careful not to share information with others without permission of the participants and their parents/guardians.

A third ethical issue I faced in this action research project was the potential for experimental bias. Because my participants knew me, spent every school day with me, and wanted to please me, it was conceivable that they might work extra hard in order to perform well in the study and "help me" with my thesis. There was little that I could do about this, but I did not discuss this research study during our study of equality and I taught this curriculum unit as I did all others. I accept that experimental bias is a limitation of doing action research in one's own classroom.

Data Analysis

As indicated, this action research study took place in my grade one classroom in a small elementary school in an urban school division in Winnipeg, Manitoba. My classroom had a total of 25 students at the time of this study, 13 female students and 12

male. A third of the students came from one parent households, and two thirds lived with both parents or spent equal amounts of time with both parents in different households. Approximately half of the students came from low socio-economic statuses and lived in lower income housing. One fifth of the students came from high socio-economic statuses, and the remainder of the students came from mid socio-economic statuses. Of these 25 students, 21 provided permission to be involved in the action research project, one student moved, and one student attended school sporadically for the duration of the study. This left 19 students, from whom I selected a diverse sampling of four students whose work I analyzed for the purposes of this thesis. These four students, Vanessa, Jackson, Isabelle, and Alexander (pseudonyms); were chosen because they represented varying academic levels, a range of socio-economic statuses and family situations, both genders, were in attendance for the majority of the time this action research project took place, and granted permission themselves and were granted permission by their parents/guardians to participate in this study.

Vanessa is a student who entered grade one with limited school academic experiences, and, at the time of this study, was striving to achieve at grade level expectations in all subject areas. She comes from a low-mid socio-economic status family with two parents and an older sibling. Vanessa is a perfectionist who struggles when faced with a concept that is unknown to her. She is not the type of student to "jump right in"; she'd rather watch, get the facts, and then share her ideas.

Jackson is a student who, at the time of this study, faced many challenges with grade one academics, in all subject areas. He comes from a low socio-economic status family and he has a single parent and an older sibling. Jackson is in a hurry to complete

his work so that he can play. He would choose to play over reading, writing, discussing concepts or participating in other class activities.

Isabelle is a student who, at the time of this study, was achieving well above grade level expectations in all subject areas. She is a prolific reader and writer who enjoys helping others whenever the opportunity presents itself. She is also a year older than the rest of the students because she lived in another country for several years, and because of when her birthday occurs she was not allowed to start kindergarten until a year later than she would have in Canada. She comes from a high socio-economic status family and has two parents, an older sibling and two younger siblings.

Alexander is a student who, at the time of this study, was achieving grade level expectations in all subject areas. He is outgoing with great confidence in his academic abilities. He eagerly shares his ideas, and enjoys figuring things out both on his own and with others. Alexander comes from a mid-level socio-economic status family and he has two parents and a younger sibling.

To begin analyzing the data, I reviewed the information gathered from the four selected students' pre- and post-questionnaires, student writing samples, teacher-researcher observations, and researcher field notes, with the intent to "give voice to those participants and provide a body of ideas and concepts that clearly mesh with important elements of their experience and provide the basis for action" (Stringer, 2004, p. 98). In my review of the data I attempted to identify epiphanies or critical incidents - "illuminative or transformative moments" (Stringer, 2008, p. 89). This process was designed to ensure that individual perspectives and expressions were effectively represented. Following the identification of epiphanies, I examined their relationship to

the existing literature and identified common perspectives, experiences, and points of discrepancy and/or conflict (Stringer, 2004).

Research Quality

Action research "is designed for practical purposes having direct and effective outcomes in the settings in which it is engaged" (Stringer, 2004, p. 2). Teacher-researchers who engage in action research do so to acquire understandings that have useful applications for their educational practices. Action research is a cyclical process of systematic inquiry that encourages teacher-researchers to "look, think, act" (Stringer, p. 13).

To ensure quality research throughout this study, I kept in mind Wolcott's (as cited in Mills, 2007) strategies for ensuring the validity of action research, including: talking a little and listening a lot, recording observations accurately, beginning to write field notes early and continuing to write consistently, and allowing the readers of my study to "see" actual examples of data for themselves (I have included samples of student math journal entries). Additionally, I reported as fully as I could on all aspects of the study and data collected, I was candid and sought feedback from participants, and I wrote as honestly and accurately as possible, sharing knowledge gained through the implementation of this action research project.

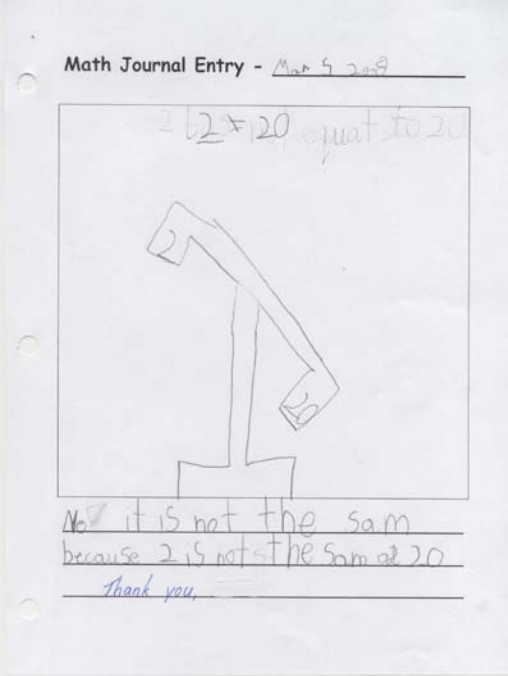
Because this action research project is qualitative action research, I also kept in mind Guba's (as cited in Mills, 2007) criteria for validity of qualitative research. This criteria includes: credibility, which I strove to achieve through persistent observations and by practicing triangulation; transferability, which I attempted to realize through detailed, descriptive data collection; dependability, which I tried to attain by overlapping

methods and establishing an audit trail of student work samples; and, confirmability which I sought to accomplish by triangulating the data and by practising reflexivity through researcher field notes/reflections.

Chapter IV: Results and Discussion

Before I begin analyzing the students' journal entries, I want to share my agreement with Wilde's (1991) insight that writing-to-learn in mathematics includes representing as well as writing. Undertaking this study in a grade one classroom reiterated the importance of this statement for me. Many of my students were often unable to share their entire and/or complete thoughts in writing. Yet, upon review of their drawings, I was able to grasp what they were communicating. My students often did not have the language and/or writing capacity to share their detailed knowledge of a subject. Providing students with another avenue to explain themselves proved eye-opening for me, both as a teacher and as a researcher. This helped me to be a better teacher as I gained understanding of my students' comprehension of the content area, beyond what they were able to express in writing.

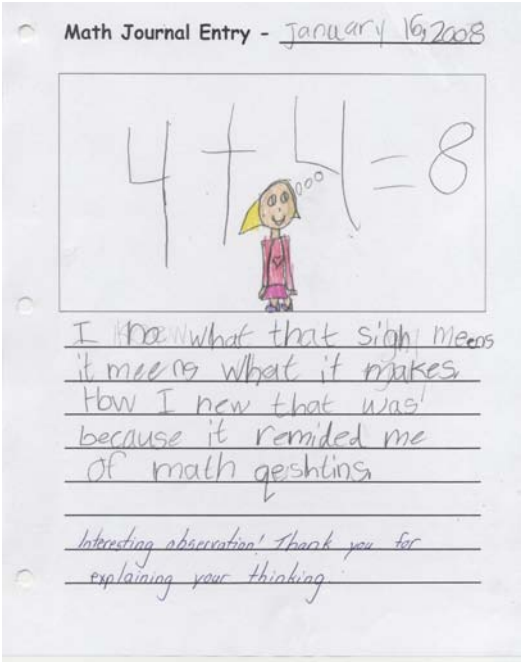
Figure 2 is a journal entry by Vanessa that illustrates how viewing a student's representation clarified my understanding of her knowledge much more so than just reading her writing. On March 5, 2008 I asked the students to "show me an inequality statement and explain why it is not equal". Through her representation Vanessa demonstrates a solid understanding of the not equal symbol, and uses it to communicate a correct inequality statement. Her representation also exhibits her ability to use a balance scale to demonstrate inequality. Her writing indicates that the two numbers she provided were not equal, but she does not explain why they are not equal. The scale in her representation shows that 20 is larger (heavier) than two. It is through Vanessa's representation that I was able to determine her understanding of the concept.



No it is not the same because 2 is not the same as 20.

Figure 2. Vanessa math journal entry, March 5, 2008

Beginning this action research study with three math journal entries to establish a basis of prior knowledge provided me with a first-hand appreciation for Borasi & Rose's (1989) position that students view mathematics as a subject with one right answer. All four of the students selected for this study indicated in their math journal entries that the = symbol was used to answer a mathematical equation. According to the Western and Northern Canadian Protocol (WNCP), upon which the new Manitoba mathematics curriculum is based, students need to understand that the equal symbol (=) does not mean 'the answer', or 'what it makes', but rather, it means 'the same'; meaning that whatever is on opposite sides of the symbol is the same.



I know what that sign means. It means what it makes. How I knew that was because it reminded me of math questions.

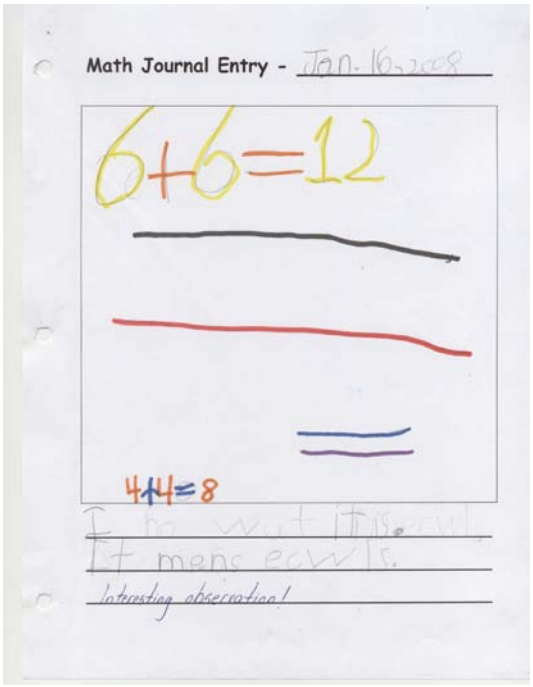
Figure 3. Isabelle math journal entry, January 16, 2008

I think it means equal.

Figure 4. Jackson math journal entry, January 16, 2008

This symbol means equals. I know it because we do it in math.

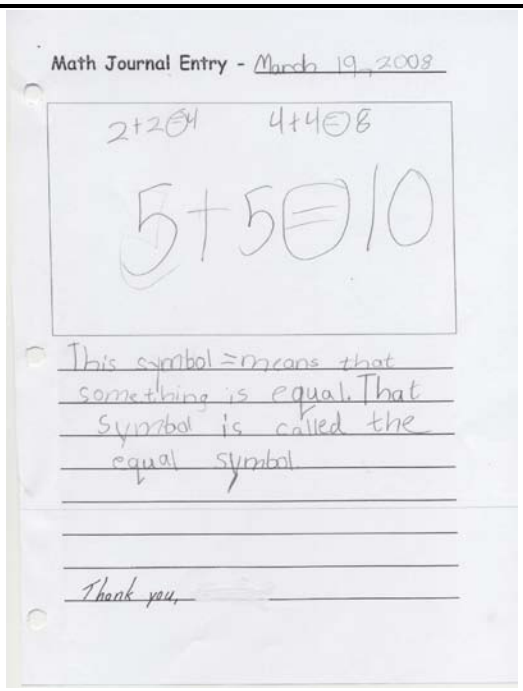
Figure 5. Alexander math journal entry, January 16, 2008



I know what it is. It means equals

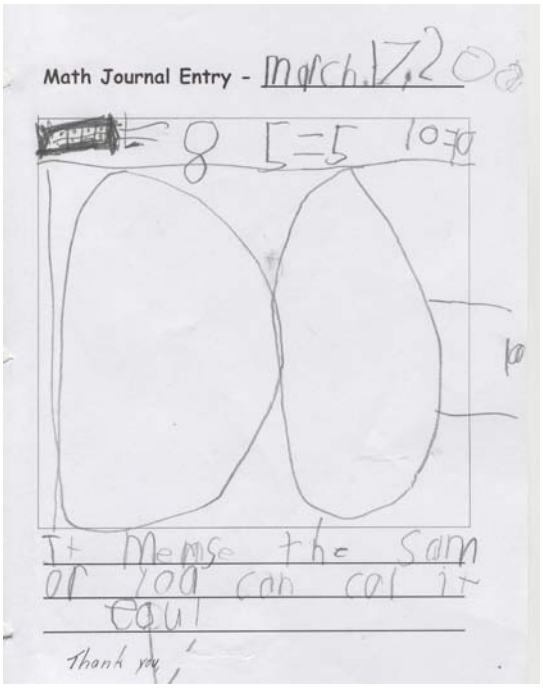
Figure 6. Vanessa math journal entry, January 16, 2008

Upon completion of this study, all four of these students were able to clearly communicate a revised understanding of the equal symbol; demonstrating in their use of writing-to-learn in mathematics that their understandings of the content area had increased.



This symbol (=) means that something is equal. That symbol is called the equal symbol.

Figure 7. Isabelle math journal entry, March 19, 2008

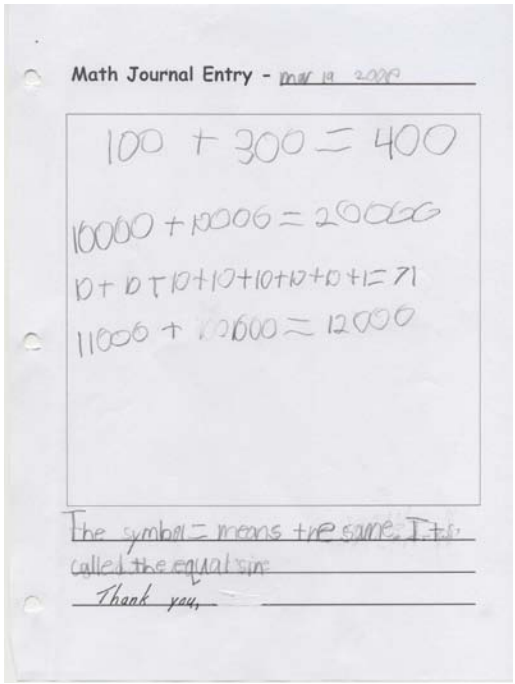


Representation: A ten frame with eight dots is equal to the number eight.

5 = 5. 10 = 10. 100 = 100

Text: It means the same or you can call it equal.

Figure 8. Jackson math journal entry, March 19, 2008



Representation: 100 + 300 = 400.

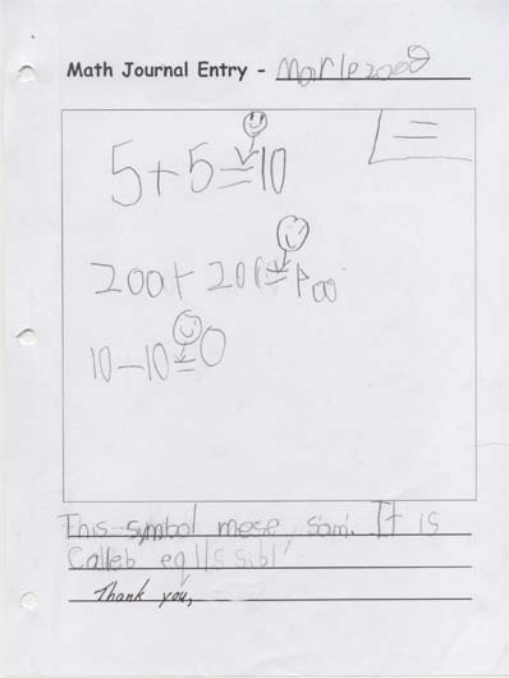
10 000 + 10 000 = 20 000.

10 + 10 + 10 + 10 + 10 + 10 + 10 + 1 = 71.

11 000 + 1 000 = 12 000

Text: The symbol (=) means the same. It is called the equal sign.

Figure 9. Alexander math journal entry, March 19, 2008



The symbol means same. It is called equals symbol.

Figure 10. Vanessa math journal entry, March 19, 2008

McIntosh (1991), Graves (1983), and Stanton (1980) all state that writing-to-learn through the use of dialogue journals opens the lines of communication between students and teachers. Following the same idea, Gordan and MacInnis (1993), Jurdak and Zein (1998), and Miller (1991) believe that math journals facilitate one-on-one teacher-to-student communication. Gordan and MacInnis continue this concept one step further by maintaining that math journals provide a practical manner for a teacher to 'listen' and 'talk' to each individual student on a regular basis. Previous to completing this study, I thought this made perfect sense, as it was just the nature of the program that math journals would increase communication between students and the teacher. I mean, if I am reading and responding to each student's entry after each writing period, then of course we are communicating regularly, and yes I am gaining the opportunity to 'listen' and 'talk' to each student individually. Conversely, the aspect that I was not so certain about

was the dialogue component with the students. I was not sure if the students would even take the time to read how I responded to their writing, never mind answer my questions/comments. However, these researchers findings are ones with which I can personally and whole-heartedly agree now that I have completed this action research project. Every day, upon opening their math journals, the first thing many students did was look to see what I had written on their last entry. They would then often discuss this with their friends, sharing responses, and/or write back to me. When students completed writing in their math journals for the day, they would regularly ask me when we'd be doing math journals next so that they could see what and how I responded to their writing (anecdotal teacher-researcher observations, 2008). Figures 11 and 12 exhibit this phenomenon.

Figure 11 is a math journal entry written by Alexander on January 24, 2008. Upon answering the question I asked of the class and handing in his math journal, I read and responded to Alexander's writing with a question in order to extend his thinking. Before writing a new journal entry Alexander looked back to see how I had responded to his work, and then wrote back to me. This demonstrates the open communication that writing-to-learn fosters. Figure 12 is a math journal entry written by Isabelle on January 31, 2008 in response to the question, "Is 6 + 2 equal to 4 + 4? How do you know?" Similar to Figure 11, this entry demonstrates the communication that writing-to-learn facilitates between students and teachers. Isabelle answers the original question, and at a later date, responds to the secondary question I wrote just for her in order to clarify her thinking. These two figures are just two of many examples of how writing-to-learn in the

form of dialogue journals provides the opportunity for increased content area communication between students and teachers.

Figure 11. Alexander math journal entry, January 24, 2008

Alexander (original entry): Yes, they are equal because 5 + 1 = 6. There are 6 dots on the dice and there are 5 + 1 fingers.

Teacher: Great explanation! What else equals six?

Alexander (response): 2 + 4 = 6

Figure 12. Isabelle math journal entry, January 31, 2008

Isabelle (original entry): Yes, they are equal. I knew that because I looked at the first problem and it [is] equal and eight and eight are the same.

Teacher: Do 6 + 2 and 4 + 4 both make 8?

Isabelle (response): Yes, they do.

While writing my analysis of this data, I saw something in figure 11 that called for further self-reflection. My principal reason for doing my Master of Education degree was to improve my teaching. I chose this particular topic for my thesis because I saw this as an area in need of additional research, it is an area that has changed dramatically, curriculum-wise, in the last few years, and it is an area in which I thought I could improve my teaching. I noted early in this paper that many of my students were under the impression that equal meant "it makes", not "the same", as indicated in the new curriculum. So imagine my dismay, when rereading and reflecting upon the students journal entries and my responses, when I see how I responded to Isabelle's entry on January 31, "Do 6 + 2 and 4 + 4 both make 8?" Yikes! I used the exact wording to ask a question that I am telling my students not to use! This just goes to show how much the previous understanding of the equal symbol has permeated my thought process. Even when I am consciously aware that equal does not mean "it makes", that is the language I used to respond to a student. And on top of that, I didn't even realize this error until the final revisions for this thesis were well underway! Luckily, I don't believe that my error resulted in any confusion on Isabelle's part, as she seems to have a solid understanding of the concept of equality. Due to my disappointment at this personal error, I doubt I will make this mistake again, which in the long run is a benefit for both me and my students, and something I would not have noticed without this action research process.

The back and forth communication that the math journals prompted in my classroom also helped the students to review, refocus, and reconsider learned topics as stated by Azzolino (1990). For example, Isabelle clearly had some background knowledge of both equality and inequality prior to beginning this unit of study. However,

the chance to write in her math journal increased her understanding of the content, and allowed her the opportunity to review her prior knowledge, and refocus her previous understandings based upon the new knowledge that she gained through writing to learn. The first question I asked the students to respond to in their math journals was, “What is equality?” Isabelle answered this question correctly (figure 13) , but when asked this question again at the conclusion of the study (figure 14) it is evident how much her thinking has been refocused with the use of writing to learn in mathematics.

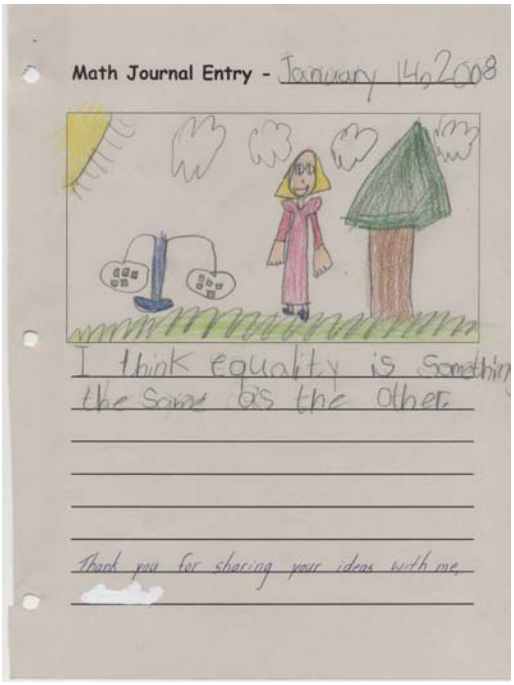
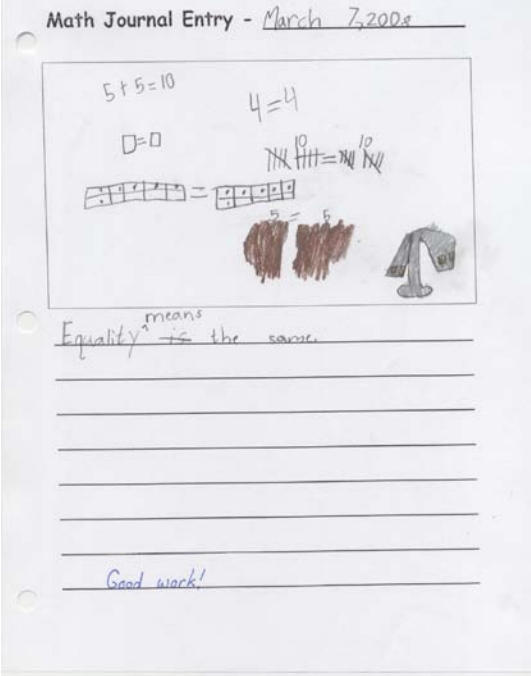


Figure 13. Isabelle math journal entry, January 14, 2008

I think equality is something the same as the other.



Representation: 5 + 5 = 10. 4 = 4. 0 = 0. Six on a ten frame is equal to six on a ten frame. Five fingers is equal to five fingers. Two of the same object on either side of a scale are equal.

Text: Equality means the same.

Figure 14. Isabelle math journal entry, March 7, 2008

According to Manitoba Education Citizenship and Youth (2006) assessment document, writing-to-learn in mathematics can be a beneficial assessment *for* learning tool. Several researchers in the field agree that it can provide educators with information about student understandings, feelings, misconceptions, and help to drive instruction (Borasi & Rose, 1989; Gordan & MacInnis, 1993; Hackett & Wilson, 1995; Huggins & Maiste, 1999; Ishii, 2002; Koirala, 2002; LeGere, 1991; MacGregor, 1990; McCallum & Whitlow, 1994; McIntosh, 1991; McIntosh & Draper, 2001; Miller, 1991; Miller, 1992; Phillips & Crespo, 1995; Pugalee, 1997; Pugalee, 2001; Schwarz, 1999; Wilde, 1991). MacGregor elaborates on this idea, stating that the addition of writing-to-learn in mathematics to regular mathematics programming does not take time away from instruction. Rather, math journals improve instruction because the teacher gains insights into student understanding, and can better determine future instruction based on reading students' writing, where misconceptions and gaps in knowledge are often revealed.

From my personal teaching experiences I know there have been times when my students have not understood a concept, and it has taken me a while to figure out where the misconceptions were, and who did and did not understand. When reading math journal entries, it was easy to tell when a concept was not understood by all students. Additionally, I was able to tell what part of the concept was confusing the student(s), which made re-teaching the concept much more effective. On January 31, 2008 I asked the students "Is 6 + 2 equal to 4 + 4? How do you know?" The resulting student math journal entries did not make me feel like a very effective teacher (though, on the plus side, the researcher in me found this entire experience very valuable). It was obvious from reading the students' math journal entries, that I had jumped ahead with this question, and that the majority of students did not understand the concept (anecdotal teacher-researcher observations, 2008). Figure 15 is a math journal entry by Vanessa that demonstrates her misunderstanding. She did not believe that 6 + 2 and 4 + 4 were equal. It is interesting to note, however, that upon close evaluation of her representation you can see that she erased the scale she had drawn originally, which showed 6 + 2 balanced with 4 + 4. Her revised representation is that of an uneven balance scale with the 6 + 2 being weighted lower on the scale (reflecting a larger mass) than 4 + 4. I believe this indicates that she is beginning to understand the concept of showing equality using number sentences (i.e. having a number sentence on either side of the equal symbol, rather than the traditional view of one number sentence equals a single number), but is having trouble assimilating that with her prior understanding that equal means 'answer'.

No it is not the same because 6 + 2 is not the same as 4 + 4.

Figure 15. Vanessa math journal entry, January 31, 2008

Reading Vanessa's math journal entry (which was similar to the majority of the class' math journals) required me to rethink my lesson plans, go back, and re-teach the concept showing equality with number sentences. I returned to this troublesome topic, and actually took a few steps back, during the next mathematics class. On February 1, 2008 I reviewed the concept of equality using number sentences, but this time we only went as far as a number sentence on one side of the equal symbol with a single number or numeral representation on the other side (rather than number sentences on both sides of the equal symbol as in the last lesson). After the lesson, I asked the students to respond to the following question in their math journals: "Is 10 equal to 5 + 5?" This time all of the students were able to correctly identify that 10 is equal to 5 + 5, and explain their thinking through either writing and/or representations (see figure 16, Vanessa's entry, in comparison to her previous entry).

Yes 5 + 5 = 10. It is the same because 5 + 5 = 10.

Figure 16. Vanessa math journal entry, February 1, 2008

Once again, Vanessa's writing does not provide insights into her thinking. However, her representation of a balanced scale, demonstrates her understanding that 5 + 5 is the same, or equal to 10.

The regular writing of students in their math journals, along with my daily reading of their writing, resulted in my quick observation of a lack of understanding for a large majority of the class. By reading the students' journal entries and determining what required clarification, I was able to revise my lesson planning, and on the very next day review the misunderstood concept and refocus students' understandings. I can honestly say that without math journals I may have eventually noted confusion on the part of the students. But, likely it would have taken me several days to determine exactly what the students' misunderstandings were, and I may not have noticed exactly who was having difficulty. Consequently, I may have chosen to review the concept in a small group,

rather than with the whole class, leaving some students without the review they required. Therefore, I concur with MacGregor (1990) and Borasi and Rose (1989) that math journals do not take time away from instruction. Instead, they can help to improve instruction by bestowing teachers with "a wealth of information usually unavailable to them" (p. 362), and providing teachers with intimate knowledge of individual student's thinking through the continuous dialogue that math journals generate.

Throughout the course of this study, I observed an improvement in the students' attitudes towards mathematics. Figures 17, 18, 19, and 20 compare the first three questions on both the pre- and post-questionnaires for the students in the study and the class as a whole. The first three questions pertain to attitudes towards mathematics:

1. How does math make you feel?
2. Do you understand math?
3. Is math fun?

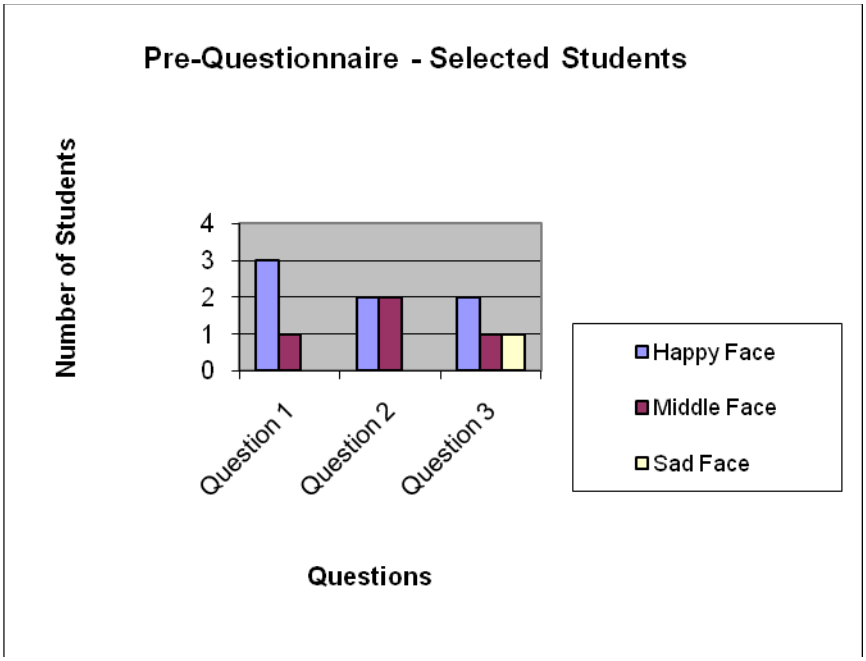


Figure 17. Pre-Questionnaire - Selected Students –attitudes towards mathematics

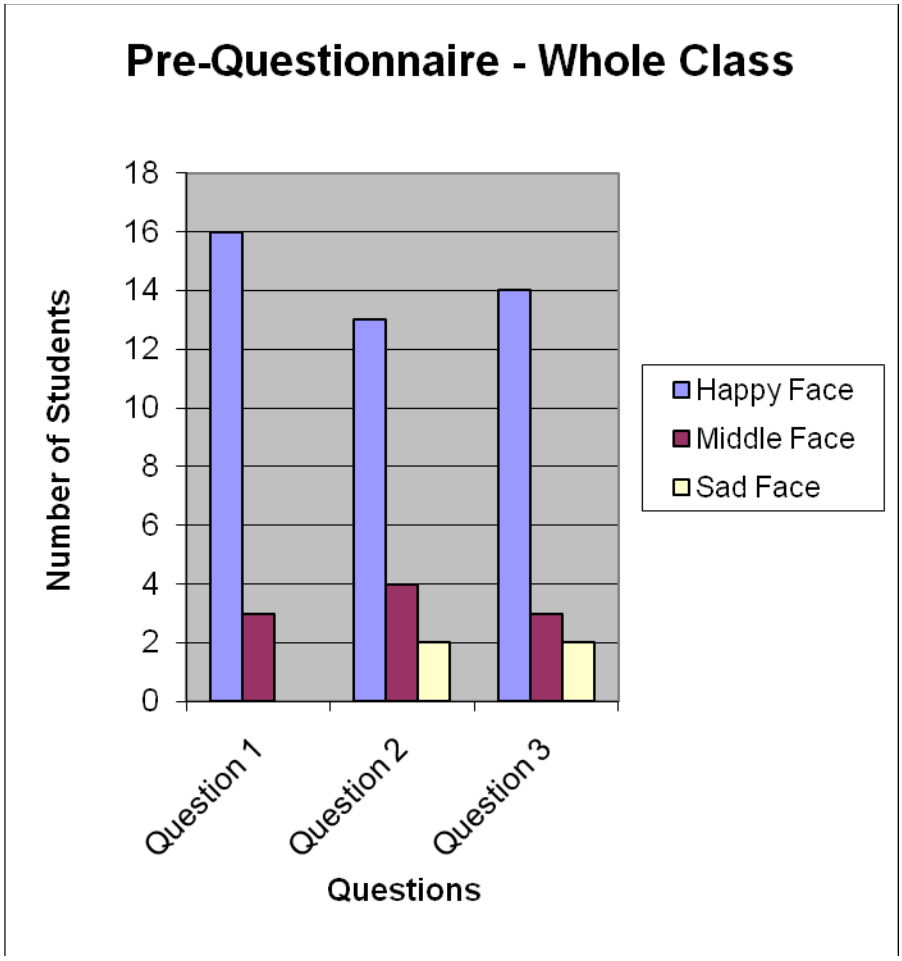


Figure 18. Pre-Questionnaire – Whole Class –attitudes towards mathematics

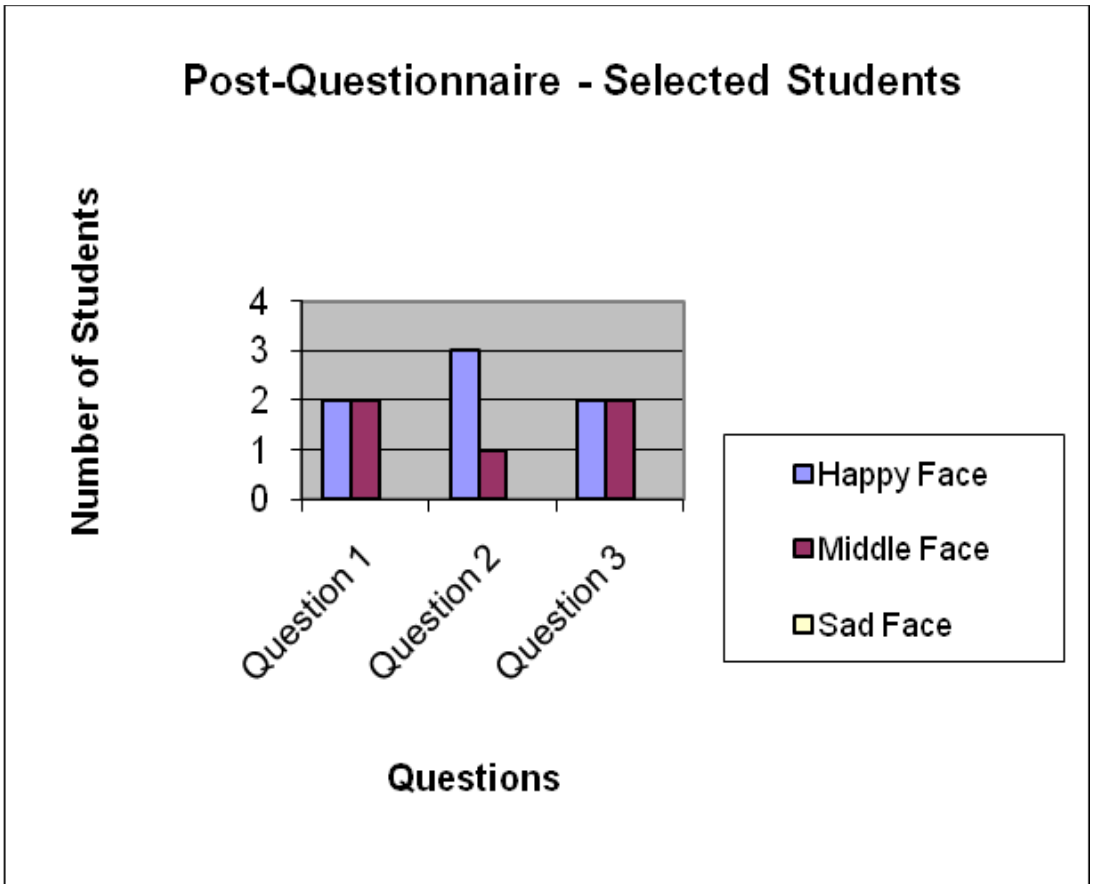


Figure 19. Post-Questionnaire-Selected Students –attitudes towards mathematics

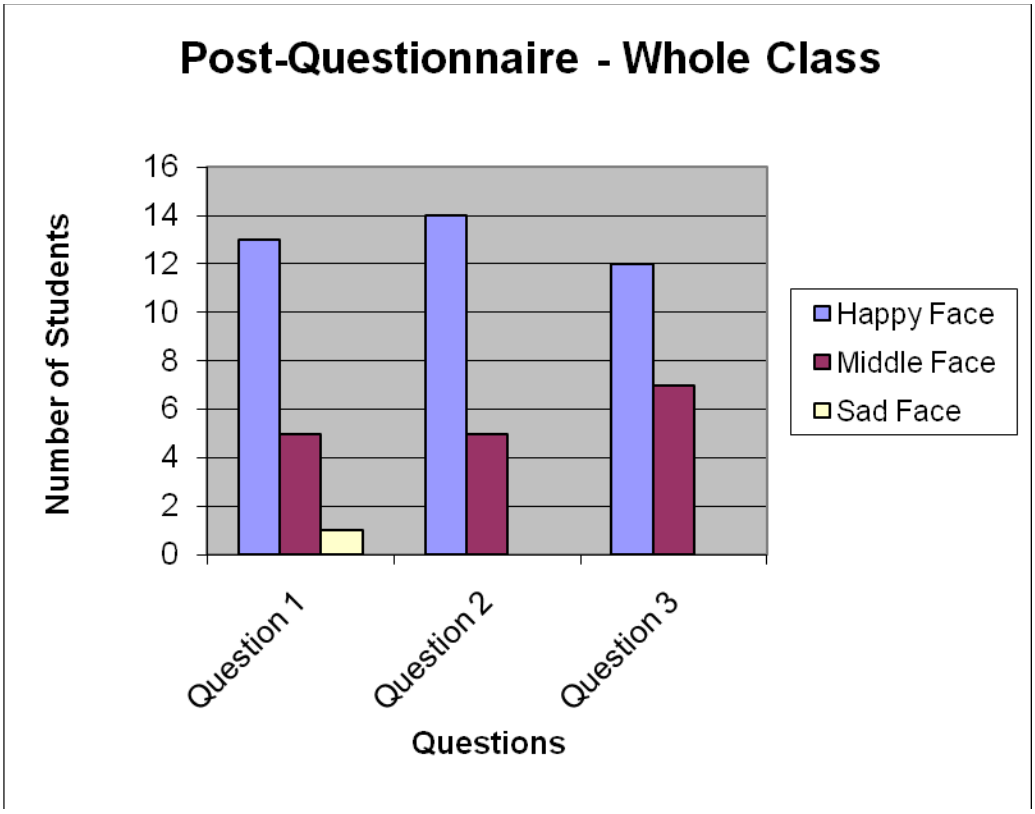


Figure 20. Post-Questionnaire-Whole Class –attitudes towards mathematics

A comparison of the pre-and post-questionnaires for both the selected students and the entire class, indicated that the children's attitudes toward mathematics had improved at the conclusion of the study; there were more happy faces and a minimal number of sad faces recorded. Reading students' journal entries also helped to demonstrate for me the positive improvement in attitude towards mathematics during the course of this study. Figure 21 is an open-ended journal entry written by Jackson on February 26, 2008.

I understand Mrs. Amaral because I learned math.

Figure 21. Jackson math journal entry, February 26, 2008

As stated earlier, at the start of this action research project Jackson was a student who would consistently rush through his work and would rather play than read, write, discuss concepts, or participate in class activities. During this opened-ended journal entry, Jackson took his time to share his pleasure and confidence in recently acquired knowledge, as well as drawing a detailed picture. He did not rush through his writing and drawing; he took pride in his writing; thereby, reinforcing the claims of Anderson and Little (2004), Blessman and Myszczak (2001), Borasi and Rose (1989), Hackett and Wilson (1995), Huggins and Maiste (1999), Ishii (2002), and Schwarz (1999), that writing-to-learn in mathematics has a positive effect on students' attitudes, self-confidence, and motivation towards their learning.

Gordan and MacInnis (1993), Huggins and Maiste (1999) and Koirala (2002) all found that students enjoyed writing in their math journals. This is another finding with which the data from this study concurs. Through daily observations of the students, as

well as in their responses to question five on the final questionnaire, "How do you feel about writing in your math journal?" (Figure 22), it was obvious to me that the students took pleasure in writing in their math journals. On February 8, 2008, almost a month after we first started writing in math journals, I handed out the students' journals while they were out of the classroom. Upon entering the classroom, several students exclaimed, "Yay! Math journals!" and the excited buzz built up from there. I gave the students a few minutes to read my comments on previous entries and write responses if they wanted, and after approximately five minutes the students started asking what the day's question was because they wanted to get started! This was exciting to see. The students really were enjoying writing in their math journals (anecdotal teacher-researcher observations, 2008).

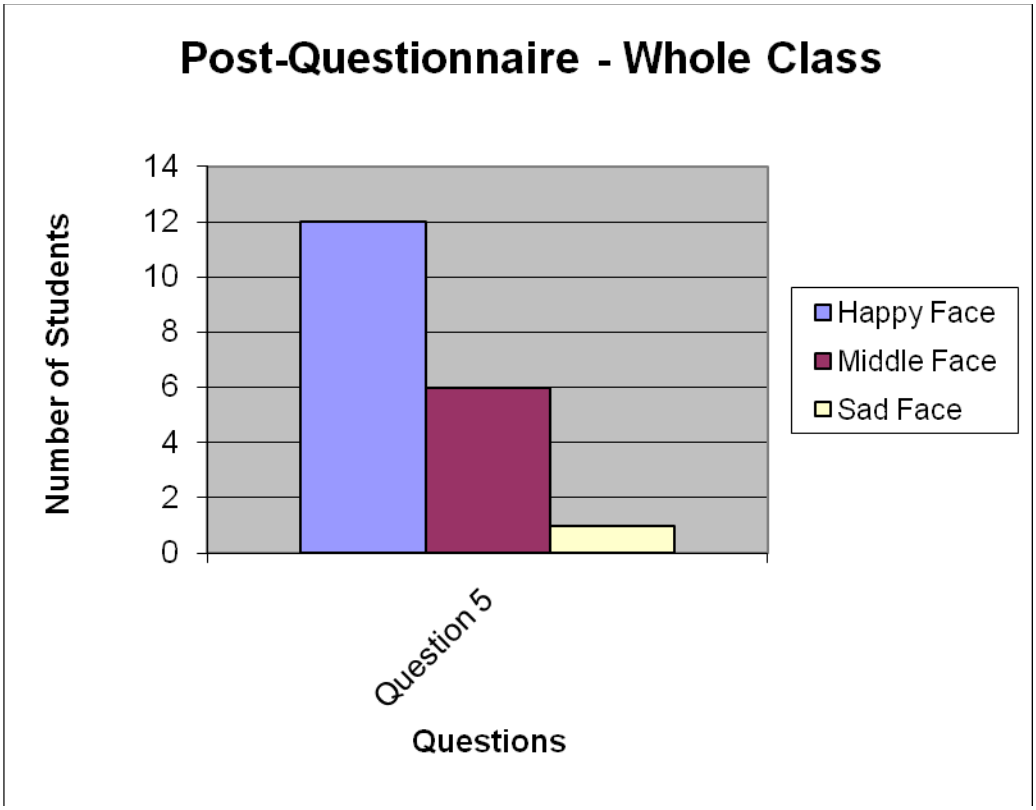


Figure 22. Post-Questionnaire (Whole Class) question five –"How do you feel about writing in your math journal?"

Having my students writing in math journals provided me with the opportunity to view their thinking processes - a phenomenon also noted by Chapman (1996). This window into students' thinking is invaluable, beyond determining if a student has answered a question correctly and theoretically understands the concept. It supplies information about how a student reached the answer he/she did, which demonstrates the depth of a student's understanding, or conversely identifies the nature of the student's misconceptions. Figures 24 and 25 illustrate this 'window' into students' thinking that can be provided by math journals.

Figure 23 shows the question and corresponding illustration that I provided to the students and to which I asked them to respond on January 21, 2008.

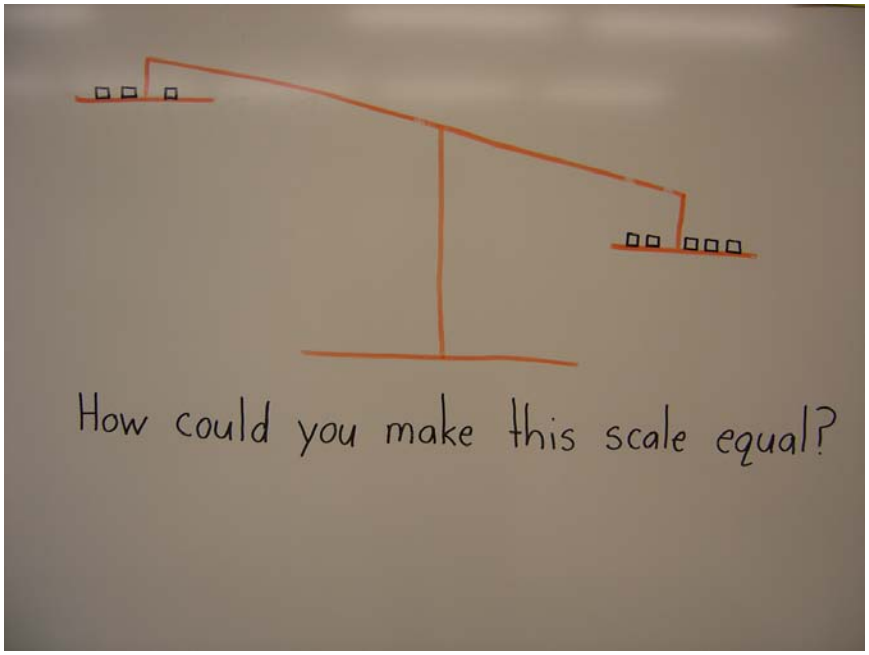


Figure 23. Math journal question on January 21, 2008

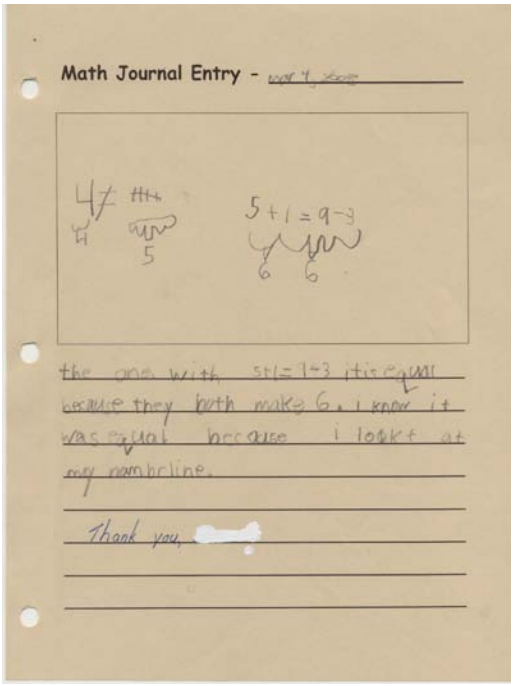
Jackson's written response and corresponding representation (figure 24) to the above question informed me that he has a basic understanding of equality, by changing the blocks on the scale to be the same on each side. Additionally, changing his scale to

display equality in a balanced state, and by labelling his picture (upon my request), he revealed further understanding and showed me that his thinking process included an enhanced understanding of equality.

I put four in the low (side of the scale) to make [it] equal.

Figure 24. Jackson math journal entry, January 21, 2008

Figure 25, is a math journal entry written by Alexander on March 4, 2008. Previous to this entry, I thought Alexander understood equality and inequality. However, this written response provided me with an in-depth appreciation for his detailed understanding of the concepts. I asked the question: "Which statement is true? 4 = 𝍸 or 5 + 1 = 9 – 3? How do you know?"



The one with 5 + 1 = 9 – 3 is equal because they both make six. I know it was equal because I looked at my number line.

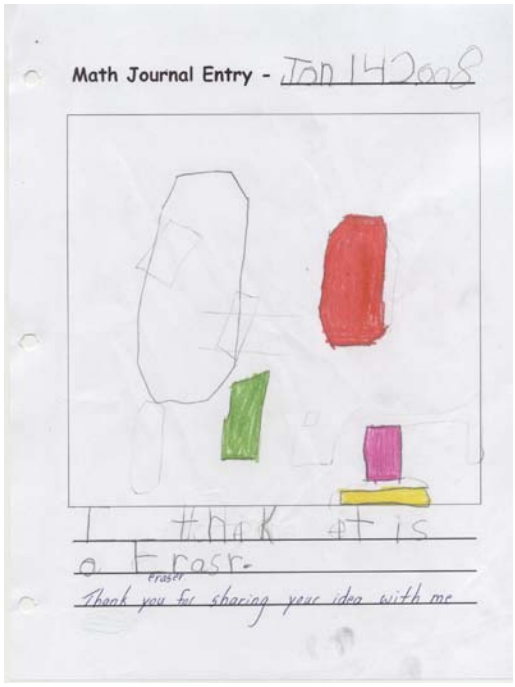
Figure 25. Alexander math journal entry, March 4, 2008

In this math journal entry, Alexander is able to communicate his understanding through his representation and condensing the number sentences into smaller pieces to show equality, as well as use the correct symbols for both equality and inequality. His writing further clarifies his thinking by telling me that both sides of the longer number sentence equal six, so they are the same. I have no doubt after reading this entry that Alexander has a thorough understanding of the topics at hand, though he continues to use the term 'make' rather than 'is the same as'.

Many researchers argue that writing-to-learn in mathematics is an effective means of increasing students' understandings of, and vocabulary about mathematical concepts (Bangert-Drowns Hurley, & Wilkinson, 2004; Blessman & Myszczak, 2001; Borasi & Rose, 1989; Fortescue, 1994; Gordan & MacInnis, 1993; Hackett & Wilson, 1995; Ishii, 2002; Jurdak & Zein, 1998; Koirala, 2002; LeGere, 1991; McIntosh, 1991; Miller, 1991; Schwarz, 1999; Wilde, 1991). Additionally, math journals provide students with the

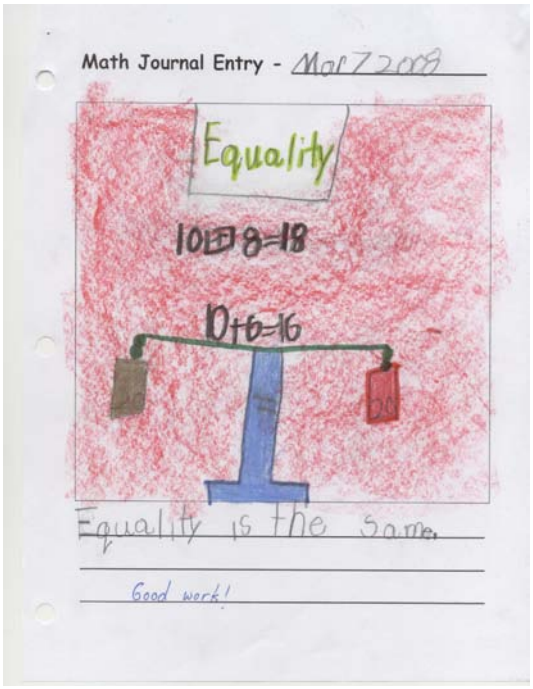
opportunity to learn, practice, and communicate using this specific vocabulary (Schwarz, 1999). Throughout the course of this study, I have observed the students' vocabulary grow to include the words equality and inequality, and their understandings of these developing concepts. At the start of this study, only Isabelle was able to tell me what equality and inequality meant, and even she was not certain – it was tentative hypothesis. Over the course of the students' many math journal entries, I observed their understandings grow and vocabularies increase to include the correct usage and definition of the studied terms and their corresponding symbols and concepts. By the conclusion of the study, all four students were able to explain in writing, and through their representations, equality and inequality in detail; thereby, demonstrating their developing vocabulary and understanding of the learned concepts.

Figures 26 and 27 are Vanessa's responses to the question asked at both the start and conclusion of the study: "What is equality?" These math journal entries demonstrate her developing understanding of the term equality and its meaning. At the start of the study, Vanessa had no prior knowledge of the term equality or its meaning. At the conclusion of the study, she is able to define the term correctly, as well as provide several examples that illustrate equality.



I think it is an eraser.

Figure 26. Vanessa math journal entry, January 14, 2008



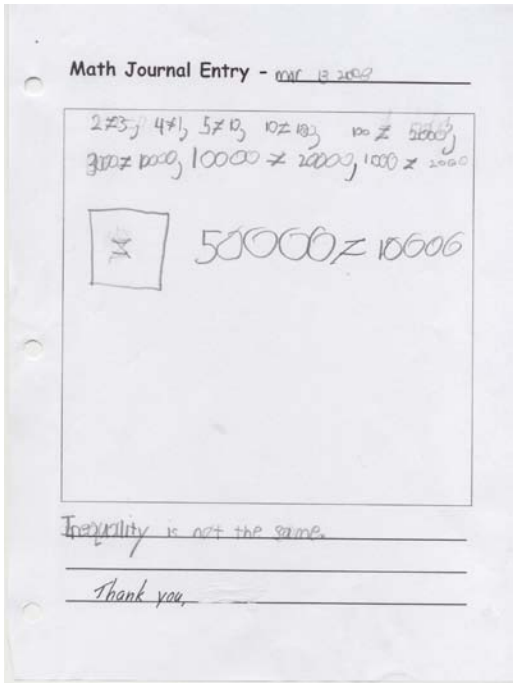
Equality is the same.

Figure 27. Vanessa math journal entry, March 7, 2008

Figures 28 and 29 display Alexander's growth in understanding and vocabulary for the term inequality. These math journal entries were written in response to the question: "What is inequality?" At the start of the study, Alexander thought the term inequality had something to do with mathematics, but he did not know what. At the conclusion of the study he is able to define inequality, as well as provide several examples of inequality in practice.

I don't know what inequality is, but I think it is math.

Figure 28. Alexander math journal entry, January 15, 2008



Inequality is not the same.

Figure 29. Alexander math journal entry, March 13, 2008

A big part of a primary classroom teacher's job is record keeping. We need to have information about student progress and achievement at our fingertips for parents, planning, and reporting purposes. Math journals provide teachers with a record of student growth and understanding (McIntosh, 1991). Blessman and Myszczak (2001) maintain that in addition to being an assessment *for* learning tool, math journals are also an assessment *of* learning tool because they demonstrate student understanding and comprehension of the concepts taught. Hackett and Wilson (1995) agree, stating that it is apparent students understand ideas if they can write clearly about them. I chose to use the student math journal entries as an assessment *for* learning rather than an assessment *of* learning. However, the three questions that I asked the students at the start and at the conclusion of the study, when used as a comparison, are helpful for determining final understanding, or assessment *of* learning. When comparing the students' answers to

these three questions at the start and at the conclusion of this study, it is obvious that student comprehension and understanding of equality, inequality, and the equal symbol increased during the duration of this study. At the conclusion of the study, all four students were able to correctly define and provide examples of equality, inequality, and the equal symbol. Whereas at the start of the study only Isabelle had a basic understanding of equality and inequality, and although all four students had some knowledge of the equal symbol, it was incomplete and/or incorrect. At the conclusion of the study their understandings of the equal symbol are much more in-depth (anecdotal teacher-researcher observations, 2008) and encompass both the traditional explanation (answer) and the current understanding (the same). Whether this can be attributed directly to the use of writing-to-learn in mathematics, or just exposure to the concept, is impossible to determine with certainty, but this study offers compelling evidence that the students were able to articulate the concepts in writing and through number sentences and representations – ways in which they could make their thinking visible to others.

Chapter V: Conclusion

This study helped me to explore my research questions, and in so doing to gain further insight into my students' mathematical thinking, while improving my students' communication and learning in mathematics through writing-to-learn in math journals, and determining how reading and responding to my students' writing could, and did, influence my teaching. I believe, as does Wilde (1991) that "[w]riting about mathematics is a valuable tool for everyone, from the kindergartners who are just beginning to express their thoughts in writing to mature, experienced teachers" (Wilde, 1991, p. 43). Engaging my grade one students as participants in writing-to-learn in mathematics proved to be an enlightening experience, providing me with much information about my students' learning, thinking, and communicating.

At the conclusion of this action research study, I am able to answer my four research questions.

1. How can I gain further insights into my students' mathematical thinking?
2. Can writing-to-learn in mathematics, in the form of math journals, improve students' communication in mathematics?
3. Can writing-to-learn in mathematics, in the form of math journals, improve students' learning in mathematics?
4. How will reading and responding to students' writing in math journals influence my teaching?

The process of writing-to-learn in mathematics though the use of math journals provided me with many insights into my students' mathematical thinking, as evident in the samples of student writing. Through reading student math journal entries, I was constantly

informed of student progress. This teaching-learning process of writing-to-learn in mathematics was of benefit to me and the students, as it provided clear answers for identifying what the students needed to learn and helped to drive instruction as an assessment *for* learning tool. This result fits in with the findings of several other researchers (Borasi & Rose, 1989; Gordan & MacInnis, 1993; Hackett & Wilson, 1995; Huggins & Maiste, 1999; Ishii, 2002; Koirala, 2002; LeGere, 1991; MacGregor, 1990; McCallum & Whitlow, 1994; McIntosh, 1991; McIntosh & Draper, 2001; Miller, 1991; Miller, 1992; Phillips & Crespo, 1995; Pugalee, 1997; Pugalee, 2001; Schwarz, 1999; Wilde, 1991). Writing-to-learn in mathematics, in the form of math journals, was also helpful in improving my students' communication and learning in mathematics, reiterating the claims of fellow researchers (Bangert-Drowns Hurley, & Wilkinson, 2004; Blessman & Myszczak, 2001; Borasi & Rose, 1989; Fortescue, 1994; Gordan & MacInnis, 1993; Graves, 1983; Hackett & Wilson, 1995; Ishii, 2002; Jurdak & Zein, 1998; Koirala, 2002; LeGere, 1991; McIntosh, 1991; Miller, 1991; Schwarz, 1999; Stanton, 1980; Wilde, 1991). By the end of the study, all students were comfortable writing in their math journal and using this as a means to communicate with me; and all students had increased understanding of, and vocabulary in, mathematics, specifically in the areas of equality, inequality, and the equal symbol. However, the most beneficial thing that I learned from this study is an extension of question four; I learned much about myself as a teacher, and more importantly, how to be a better teacher. The day-to-day reading and responding to student math journal entries provided me with information on student learning, which directly influenced my teaching. But, the personal process of reading and responding to student math journal entries has made me a more reflective

teacher; a teacher who strives to not only know what the students understand, but to know why they understand it, and how to bridge that understanding to other concepts and future learning. Writing-to-learn in mathematics is a process I can use to develop these capacities in myself, and become a better teacher. The action research cycle of "look, think, act" (Stringer, 2004, p. 13) has definitely been in play here, as I looked at my students' learning, thought about their understandings, and changed both my day-to-day teaching and overall teaching goals.

Looking beyond my research questions, one of main understandings I developed from completing this action research study is the awareness that writing-to-learn in mathematics is good education. Writing-to-learn in mathematics provided my students with the opportunity to share their understandings with me in a one-to-one format through written dialogue, and opened the lines of communication between us; findings also shared by Gordan and MacInnis (1993), Graves (1983), Jurdak and Zein (1989), McIntosh (1991), Miller (1991), and Stanton (1980). As Gordan and MacInnis found in their research, writing-to-learn in mathematics in the form of math journals provided me with a venue to listen to each and every one of my students and to respond to them in a meaningful and detailed manner.

Writing-to-learn in mathematics in the form of math journals also provided me with the time to listen and respond to all of my students. During the course of a regular school day, teachers often do not have the opportunity to have meaningful conversations with each and every one of their students. However, because I was able to respond to students' writing after regular school hours, this process allowed me to have these detailed conversations on a regular basis, without taking away from classroom

instructional time. Therefore, I whole heartedly agree with ideas presented in MacGregor (1990) and Borasi and Rose (1989) that writing-to-learn in mathematics does not take time away from instruction, but rather improves instruction. In addition, I found that the process of writing-to-learn in the form of math journals actually provided me with supplementary teaching time, as I was more effective with my planning and teaching because I knew exactly where the students required work. I was able to maximize my teaching time and focus on my students' needs, rather than using valuable instructional time to determine what their needs were prior to instruction.

Of equal importance to the improvement in student academic achievement through writing-to-learn in mathematics is the positive change in student attitudes towards learning. As many researchers state (Anderson & Little, 2004; Blessman & Myszczak, 2001; Borasi & Rose, 1989; Hackett & Wilson, 1995; Huggins & Maiste, 1999; Ishii, 2002, Koirala, 2002; Schwarz, 1999), I also believe that writing-to-learn in mathematics had a positive effect on students' attitudes, self-confidence, and motivation towards their learning in the content area. Student attitudes were not a focus of this study, so I am reluctant to make any definitive statements regarding this belief. However, I would be interested in doing further research in this area.

I began this study with the theory that writing-to-learn in mathematics would be a beneficial activity in my classroom. Much research supported my belief, and now, at the conclusion of this study, I can say that my own research encourages these initial beliefs, as the findings fit with my beliefs about good education. These understandings will propel me to continue to explore the practice of writing-to-learn in the form of math journals in my everyday teaching.

I am quite happy with the way this action research study unfolded, I learned much from the process, and I was able to answer the questions about which I was curious at the outset of the study. However, there are a few questions that have arisen at the conclusion of this study.

1. Would the results be similar for all units of mathematics study, or do some mathematical concepts lend themselves more to writing-to-learn than others?
2. How would this study unfold if conducted with a class at a different grade level, and would the results be different?
3. Would writing-to-learn function in a similar manner in other subject areas at the grade one level? Perhaps in science?

Now that this action research study is complete I am left to ponder these questions, as well as the others I am sure will arise in the near future. I look forward to researching these questions with science journals in grade one and possibly with math and/or science journals at another grade level in the future. Now that I have begun doing action research in my classroom, I doubt that I will ever stop.

References

Anderson, M. A., & Little, D. M. (2004). On the write path: Improving communication in an elementary mathematics classroom. *Teaching Children Mathematics, 10*(9), 468-472.

Azzolino, A. (1990). Writing as a tool for teaching mathematics: The silent revolution. In Thomas J. Cooney & Christian R. Hirsch (Eds). *Teaching and Learning Mathematics in the 1990s* (pp. 92-100). Reston, VA: National Council of Teachers of Mathematics.

Bangert-Drowns, R. L., Hurley, M. M., & Wilkinson, B. (2004). The effects of school-based writing-to-learn interventions on academic achievement: A meta-analysis. *Review of Educational Research, 74*(1), 29-58.

Bechervaise, N. (1992). Mathematics: A foreign language. *Australian Mathematics Teacher, 48*(2), 4-8.

Blessman, J. & Myszczak, B. (2001). *Mathematics vocabulary and its effect on student comprehension.* Unpublished masters thesis. Saint Xavier University, Chicago, Illinois.

Borasi, R., & Rose, B. J. (1989). Journal writing and mathematics instruction. *Educational Studies in Mathematics, 20*(2), 347-365.

Brewster, C. & Klump, J. (2004). *Writing to learn, learning to write: Revisiting writing across the curriculum in northwest secondary schools*. Portland, OR: Northwest Regional Educational Laboratory.

Cai, J., Jakabcsin, M. S., & Lane, S. (1996). Role of open-ended tasks and holistic scoring rubrics: Assessing students' mathematical reasoning and communication. In P. C. Elliot & M. J. Kenney (Eds.), *Communication in mathematics, K-12 and beyond. 1996 yearbook* (pp. 137-145). Reston, VA: National Council of Teachers of Mathematics.

Chapman, K. P. (1996). Journals: Pathways to thinking in second-year algebra. *Mathematics Teacher, 89*(7), 588-590.

Crawford, K. (1996). Vygotskian approaches to human development in the information era. *Educational Studies in Mathematics, 31*, 43-62.

Driscoll, M. P. (1994). *Psychology of learning for instruction*. Needham, MA: Allyn & Bacon.

Dyson, A. H. (2004). Writing and the sea of voices: Oral language in, around, and about writing. In R. B. Ruddell, & N. J. Unrau (Eds). *Theoretical models and processes of reading* (5th ed, pp. 146-162). Newark, DE: International Reading Association.

Emig, J. (1977). Writing as a mode of learning. *College Composition and Communication, 28*(2), 122-128.

Fortescue, C. M. (1994). Using oral and written language to increase understanding of math concepts. *Language Arts, 71*(8), 576-580.

Gee, J. P. (2004). Reading as situated language: A sociocognitive perspective. In R. B. Ruddell, & N. J. Unrau (Eds). *Theoretical models and processes of reading* (5th ed, pp. 116-132). Newark, DE: International Reading Association.

Gordan, C. J., & MacInnis, D. (1993). Using journals as a window on students' thinking in mathematics. *Language Arts, 70*(1), 37-43.

Graves, D.H. (1983). *Writing: Teachers & children at work*. Portsmouth, NH: Heinemann Educational Books.

Hackett, K., & Wilson, T. (1995). *Improving writing and speaking skills using mathematical language*. Unpublished master's thesis. Saint Xavier University, Chicago, IL. (ERIC Document Reproduction Service No. ED 386 747)

Haggerty, D. J., & Wolf, S. E. (1991). Writing in the middle school mathematics classroom. *School Science and Mathematics, 91*(6), 245-246.

Halliday, M. A. K. (2004). The place of dialogue in children's construction of meaning. In R. B. Ruddell, & N. J. Unrau (Eds). *Theoretical models and processes of reading* (5th ed, pp. 133-145). Newark, DE: International Reading Association.

Hanson, J. (2001). *When writers read* (2nd ed.). Portsmouth, NH: Heinemann.

Huggins, B. & Maiste, T. (1999). *Communication in mathematics.* Unpublished master's thesis. Saint Xavier University, Chicago, Illinois. (ERIC Document Reproduction Service No. ED 439 016)

Huinker, D., & Laughlin, C. (1996). Talk you way into writing. In Portia C. Elliot & Margaret J. Kenney (Eds.), *Communication in mathematics, K-12 and beyond. 1996 yearbook* (pp. 81-88). Reston, VA: National Council of Teachers of Mathematics.

Ishii, D.K. (2002). Emergent issues in middle school mathematics action research: A meta-analysis of writing as a pedagogical strategy. Paper presented at the Annual Meeting of the Mid-Western Educational Research Association, Columbus, OH.

Jones, D. C. (1996, March). A pragmatic reconstruction of the postmodern impasse: The resounding relevance of John Dewey's tacit tradition. Paper presented at the Annual Meeting of the Conference on College Composition and Communication, Milwaukee, WI.

Jurdak, M., & Zein, R. A. (1998). The effect of journal writing on achievement in and attitudes towards mathematics. *School Science and Mathematics, 98*(8), 412-419.

Knipper, K. J., & Duggan, T. J. (2006). Writing to learn across the curriculum: Tools for comprehension in content area classes. *The Reading Teacher, 59*(5), 462-470.

Koirala, H. P. (2002). Facilitating student learning through math journals. Proceedings of the Annual Meeting of the International Group for the Psychology of Mathematics Education, Norwich, England. (ERIC Document Reproduction Service No. ED 476 099).

Krussel, L. (1998). Teaching the language of mathematics. *The Mathematics Teacher, 91*(5), 436-441.

Layzer, D. (1989). The synergy between writing and mathematics. In P. Connolly, & T. Vilardi (Eds.), *Writing to learn in mathematics and science* (pp. 122-133). New York: Teachers College Press.

LeGere, A. (1991). Collaboration and writing in the mathematics classroom. *Mathematics Teacher, 84*(3), 166-171.

MacGregor, M. (1990). Reading and writing in mathematics. In J. Bickmore-Brand (Ed.), *Language in mathematics* (pp. 100-108). Portsmouth, NH: Reed Publishing.

Manitoba Education, Citizenship and Youth. (2006). *Rethinking classroom assessment with purpose in mind: Assessment for learning, assessment as learning, assessment of learning.* Winnipeg, MB: Manitoba Education, Citizenship and Youth, School Programs Division.

Maxwell, R. J. (1996). *Writing across the curriculum in middle and high schools*. Needham Heights, Massachusetts: Allyn & Bacon.

McCallum, R., & Whitlow, R. (1994). *Linking mathematics and language*. Markham, Ontario: Pippin Publishing Ltd.

McIntosh, M. E. (1991). No time for writing in your class? *Mathematics Teacher, 84*(3), 423-433.

McIntosh, M. E., & Draper, R. J. (2001). Using learning logs in mathematics: Writing to learn. *Mathematics Teacher, 94*(7), 554-557.

Miller, L. D. (1991). Writing to learn mathematics. *Mathematics Teacher, 84*(7), 516-521.

Miller, L. D. (1992). Begin mathematics class with writing. *Mathematics Teacher, 85*(5), 354-355.

Miller, L. D., & England, D. A. (1989). Writing to learn algebra. *School Science and Mathematics, 89*(4), 299-312.

Mills, G. E. (2007). *Action research: A guide for the teacher researcher* (3rd ed.). Upper Saddle River, NJ: Pearson/Merrill Prentice Hall.

Nahrgang, C. L., & Petersen, B. T. (1986). Using writing to learn mathematics. *Mathematics Teacher, 79*(6), 461-465.

National Council of Teachers of Mathematics (NCTM). (1989). *Curriculum and evaluation standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics (NCTM). (2000). *Principles and standards for school mathematics*. Reston, VA: National Council of Teachers of Mathematics.

Palincsar, A. S. (1998). Social constructivist perspectives on teaching and learning. *Annual Reviews in Psychology*, *49*(3), 345-375.

Phillips, E., & Crespo, S. (1995, April). Math penpals: Developing written communication in mathematics. Paper presented at the Annual Meeting of the American Educational Research Association, San Francisco, CA.

Prawat, R. S. (2000). The two-faces of Deweyan pragmatism: Inductionism versus social constructivism. *Teachers College Record*, *102*(4), 805-840.

Pugalee, D. K. (2001). Writing, mathematics, and metacognition: Looking for connections through students' work in mathematical problem solving. *School Science and Mathematics*, *101*(5), 236-245.

Riddle, E. M. (1999). *Lev vygotsky's social development theory.* Retrieved March 30, 2007, from http://chd.gse.gmu.edu/immersion/knowledgebase/theorists/constructivism/vygotsky.htm

Schwarz, J. C. (1999). *Vocabulary and its effects on mathematics instruction*. Unpublished masters thesis. Saint Xavier University, Chicago, Illinois.

Staton, J. (1980). Writing and counselling: Using a dialogue journal. *Language Arts*, *57*(5), 514 – 518.

Stringer, E. (2004). *Action research in education*. Upper Saddle River, NJ: Pearson Education, Inc.

Stringer, E. (2008). *Action research in education*. Upper Saddle River, NJ: Pearson Education, Inc.

Vygotsky, L. S. (1978). *Mind and society: The development of higher mental processes*. Cambridge, MA: Harvard University Press.

Western and Northern Canadian Protocol. (2006). *Common curriculum framework for K – 9 mathematics*. Alberta, Canada: Alberta Education.

Whitin, P., & Whitin, D. J. (2000). *Math is language too*: *Talking and writing in the mathematics classroom.* Urbana, IL: The National Council of Teachers of English.

Wilde, S. (1991). Learning to write about mathematics. *Arithmetic Teacher, 38*(6), 38-43.

Willower, D. J. (1992). Dewey's theory of inquiry and reflective administration. Paper presented at the Annual Meeting of the University Council for Educational Administration, Minneapolis, MN.

Appendix 1

Math Journal Entry - _____

Math Journal Entry - _____

Math Journal Entry - _____

Appendix 2

Name _____ Date _____

Questionnaire

			
How does math make you feel?			
Do you understand math?			
Is math fun?			
Do you know what equality is?			

Appendix 3

Name _____ Date _____

Questionnaire

			
How does math make you feel?			
Do you understand math?			
Is math fun?			
Do you know what equality is?			
How do you feel about writing in your math journal?			
Did writing in your math journal help you to understand equality and inequality?			
Did writing in your math journal help you to learn?			
Did you like it when I wrote back to you in your math journal?			
Would you like to keep using your math journal?			

Appendix 4

Dear Parents/Guardians:

As a part of our regular classroom instruction, your child will be writing about his/her mathematical thinking and understanding in a math journal. Math journals will be used in conjunction with our unit of study on mathematical equality and begun on January 7, 2008 and will be completed on March 7, 2008. According to the new Manitoba mathematics curriculum, the term equality is used to show a balance and the term inequality is used to show an imbalance. For example the numeral 3 is equal to three fingers. A die showing six dots is not equal to the numeral 7, this demonstrates inequality. In addition to classroom instruction, I am also conducting a study entitled *Children's Discursive Representations of Their Mathematical Thinking: An Action Research Study*. This research is part of the requirements for a Master of Education degree in Language and Literacy through the Department of Education: Curriculum and Instruction at the University of Manitoba. It is being conducted under the supervision of Dr. Wayne Serebrin. You may contact my advisor at (204) 474-9024 or serebrn@ms.umanitoba.ca regarding this study.

The purpose of this research project is to document the implementation of writing-to-learn in mathematics, in the form of math journals. This strategy has a solid research base and several studies show that the following goals may be achieved through writing-to-learn in mathematics. The goals of writing-to-learn in mathematics are:

1. To increase students' abilities to communicate their mathematical thinking.
2. To increase mathematical dialogue between a teacher and his/her students.
3. To increase students' understanding of, and vocabulary in, mathematical concepts.
4. To assist students in developing/increasing a positive attitudes towards learning in mathematics.
5. To provide increased opportunities for teachers to get to know their students.
6. To become an assessment *for* learning tool that teachers can use to inform instruction (whole class, small group, and individualized).

At the beginning of January, I asked all students to complete a questionnaire indicating their thoughts and feelings towards mathematics, as well as their understanding of equality and inequality. Following this the students began to participate a variety of hands-on learning experiences regarding equality and inequality and writing in their math journals three times per six day cycle to support their learning. This will result in approximately twenty math journal entries per student. At the conclusion of this research I will have the students complete another short questionnaire again asking them to share their thoughts and feelings towards mathematics, their understanding of equality and inequality, and how they viewed writing in their math journals. There are no additional expectations for your child outside of the regular school expectation of always work hard.

Reading the students' math journals will provide me with the opportunity to get to know them better and adapt my instruction to best fit their needs (both as a whole class and individually). The purpose of this research is to improve classroom instruction. This project will not only serve to improve my own teaching, but it will also provide information for other teachers concerning the instruction and potential of math journals.

In the written report of this project, my thesis, I intend to include examples of students' writing, comments from the two questionnaires, observations that I collect when watching the students during instructional times, and my own personal reflections. The collection of anecdotal observations of children's learning is a regular part of ongoing assessment in the classroom and no additional tests or tasks beyond what is usually done for the purposes of assessment and reporting will be used. The University requires that permission be sought for the use of any information for the purposes of research. Therefore, I am requesting yours' and your child's permission to include selected examples of comments, observations, writing samples, and interpretations that I have collected in the classroom in my Masters Thesis Report.

In accordance with the University of Manitoba's standards for ethical research, the identities of all students will be protected. Any examples of children's work, responses, and comments used will be anonymous and pseudonyms for the children and the school will be used in the written report. All of my observational notes, personal reflections, and questionnaires will be kept secure in a locked cabinet in my classroom. The students' math journals will not be locked up, as the students will require access to them. However, they will be kept in the classroom at all times. This information will be used not only in my Masters thesis, but also for report cards, and possibly for discussion at triad conferences. At the conclusion of the research, no one other than me will have access to any information which includes the identity of the child.

Your permission for your child's responses to the questionnaires and journal writing to be used as data in the research must be voluntary and I want to assure you that there are no consequences that arise from giving or withholding your permission. The instruction in the classroom will be provided to all children regardless of whether or not the results of that instruction are used for my research. In order to alleviate any pressure you might feel because I am your child's teacher, I have asked that all returned consent forms be sent to [redacted], the school secretary, not to me. [redacted] will not reveal the names to me until June 27, 2008, the conclusion of the 2007 – 2008 school year. I have also informed the school principal [redacted] and division chief superintendent of my intended research, which they have granted permission for me to complete. Should you feel that there are pressures or unanticipated consequences as a result of participating or not, you are free to contact [redacted] my research advisor, Dr. Wayne Serebrin, or the human ethics secretariat at the University of Manitoba (204-474-7122 or Margaret_bowman@umanitoba.ca) to have your concerns addressed. If you decide to withdraw your consent you are free to do so at any time by notifying [redacted]. If permission is not given or is withdrawn, no work samples, observations, questionnaire comments, or my own personal reflections regarding your child will be used in my thesis report.

There are no known or anticipated risks to your child associated with giving consent for information to be used in my research study. Writing in the math journals will be an aspect of curricular instruction during regular school hours. Communication in mathematics is an important aspect of our provincial curriculum and writing in mathematics is a recommended teaching strategy by the National Council of Teachers of Mathematics. A potential benefit for your child is that he/she will achieve the goals set out for the research:

1. To increase students' abilities to communicate their mathematical thinking.
2. To increase mathematical dialogue between a teacher and his/her students.
3. To increase students' understanding of, and vocabulary in, mathematical concepts.
4. To assist students in developing/increasing a positive attitudes towards learning in mathematics.
5. To provide increased opportunities for teachers to get to know their students.
6. To become an assessment *for* learning tool that teachers can use to inform instruction (whole class, small group, and individualized).

This research may also benefit my own professional practice and provide information on writing-to-learn in mathematics for other teachers. A copy of my completed thesis will be left at the school and the secretary and Parent Council will be informed when it is available to be viewed by interested parties.

I will be available at your convenience to answer any questions you may have. I may be reached at the school [redacted] at home [redacted] or via e-mail samaral@sjsd.net. In addition to contacting me or my supervisor, you may verify the ethical approval of this study or raise any concerns you might have by contacting the human ethics secretariat at the University of Manitoba (204-474-7122 or Margaret_bowman@umanitoba.ca).

Please discuss this letter with your child and determine whether he or she agrees to give consent (I've attached a simplified bulleted list of what this research study entails to assist in explaining this process to your child). Your signatures below, yours' and your child's, indicate that you understand the above conditions of participation in this study and agree to allow your child to participate. You are free to withdraw from the study at any time without prejudice or consequence. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. Please return one copy of the signed consent form in the attached envelope directly to [redacted] and keep the other for your records. Thank you for your time and consideration.

Sincerely,
Samantha Shyka Amaral
[redacted] School

I give my consent for anonymous examples of my child's classroom work to be included in Samantha Shyka Amaral's Masters Thesis for the Department of Education: Curriculum and Instruction, at the University of Manitoba.

Name of Participant's Parent/Guardian	Signature	Date

Please talk about this with your child and if they consent, have them sign the form

I have asked my child, _____, who has indicated consent to have examples based on their work used in Samantha Shyka Amaral's Masters Thesis for the Department of Education: Curriculum and Instruction, at the University of Manitoba.

Name of Participating Student	Student's Signature	Date

Researcher's Signature	Date

This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully.

This research has been approved by Stan Straw of the Education/Nursing Research Ethics Board at the University of Manitoba. If you have any concerns or complaints about this project you may contact any of the above-named person or the Human Ethics Secretariat at 474-7122, or e-mail margaret_bowman@umanitoba.ca. A copy of this consent form has been given to you to keep for your records and reference.

Possible Script for Parents of Grade One Participants

- Mrs. Amaral is doing a big project called a study.

- This study will help her to pass "teacher school" (this is what I call my Masters of Education when talking to students).

- Mrs. Amaral's study is about you and your class and how you explain your thinking in math.

- You have started writing in math journals in your classroom. These math journals are a part of Mrs. Amaral's study.

- Math journals can help you to understand math better, to share your feelings about math, and to communicate your thinking in math.

- In your math journal you will be asked to answer questions, sharing your feelings, tell Mrs. Amaral what you understand, and tell her what you don't understand.

- You will write in our math journals two or three times a week. When you write in your math journal you can draw pictures and write words to explain your thoughts and ideas.

- Mrs. Amaral will write back to you in your math journal so you can have a private conversations between the two of you!

- Mrs. Amaral will also ask you to do two questionnaires, one in January and one in March. You have already completed the January questionnaire. These questionnaires are a paper with a few questions about math. To finish the questionnaire you will be colouring in happy, middle, or sad faces to tell Mrs. Amaral how you feel about math, and what you understand about math.

- To finish her project Mrs. Amaral might like to use some of your writing from your math journal, some of your thoughts from the questionnaire, and some things she notices you doing during math class.

- In order to use some of your work for her project she needs your permission, you can say yes or no and either answer is fine. You will not be "in trouble" if you say that you don't want her to use your work. That's fine, and she won't even know what your answer is. You are going to give your answer to [redacted].

- If you give Mrs. Amaral permission to use your work and then change your mind later, that's fine too. We will just call [redacted] and let her know that you don't want Mrs. Amaral to use your work and she will take your name off the list of children doing the project.

- Even if you don't want Mrs. Amaral to use your work for her study, you will still be writing in math journals, and doing the questionnaires in class. This will be a part of "doing your job".

- If it is O.K. with you for Mrs. Amaral to use some of your work in her project all you have to do is work hard. She doesn't expect your work to be perfect. She just wants you to work hard. She actually wants you to tell her if you don't understand something so that she can help you. This will help Mrs. Amaral to become a better teacher.

- If this sounds O.K. to you, and you want to give Mrs. Amaral permission to use some of your work for her project you have to sign the consent form, we have to sign the consent form, and then you have to hand it in to [redacted].