How Does Procedural Writing Influence Mathematics Achievement?

Samantha English

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Niagara University

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The current trends in educational curriculum standards are becoming more cognizant of the academic ramifications of incorporating writing into all content areas. Many authors maintain that the use of writing encourages the cognitive development of problem solving, reasoning, logical communication and the creation of context associations (Connolly & Vilardi, 1989; Maimon, Nodine, & O'Connor, 1989; Vygotsky, 1987). However, Morgan cites an "inadequate [amount of] research on writing in mathematics" (1998, p. 19). In spite of the seeming agreement among educational researchers on the importance of incorporating writing among the content areas and the vast descriptions of methods through which to implement a writing program in the mathematics classroom, very little time has been spent actually studying the impact nor have many researchers in fact analyzed the aforementioned methodologies. This begs the question; how are teachers to be expected to implement a writing program in their mathematics classrooms if there is little to no research to support its academic benefits?

In fact, in 2000, the National Council of Teachers of Mathematics [NCTM] included mathematical content writing as a major component of their communication standard and call for mathematical literacy for all. It was the belief of the members of NCTM that communication has a critical role in elucidating and advancing understanding. Under these constraints communication is best described as involving the "transmission of thoughts mediated by language" that serve as a means of constructing models of student thought and understanding (Sierpinska, 1998, pp. 32-33). This type of communication can take a multitude of forms, including but not limited to written responses and reflections, however, no matter the form, the primary purpose of the writing is to enhance the overall mathematical reasoning and cognitive functioning of students. Graves (1985), a leading researcher and advocate in the field of writing, maintains similar ideas in his research:

> Writing is a medium with which people communicate with themselves and with others at other places and times. When I write, I write to learn what I know because I don't know fully what I mean until I order the words on paper. Then I see… and know. (p. 2)

Students' first attempts to make sense of a topic are crude and unpolished. They lack the insight into their own thoughts, which prevents them from organizing said thoughts into a coherent context. Writing is an organizational framework that allows students the space to organize their communication attempts, edit them and reposition them until they are able to follow a clear plane of thought about the content idea they are learning. Writing is communication for one's self more than anyone else; it is one's place to clarify one's own knowledge and take ownership of said knowledge (Graves, 1985).

Graves reflected further on the writing process, saying, "When writers write, they face themselves on the blank page. That clean white piece of paper is like a mirror" (1985, p. 3). In looking at themselves on the blank page students are forced to face the reality of what they do know and what they don't know. This self-reflection of one's learning, mirrored in one's writing, creates a monitoring of one's own comprehension. Students can articulate what ideas make sense to them and which ideas do not, thus transforming students into metacognitive learners. In general, metacognition refers to the self-monitoring of one's own learning (Merriam-Webster, 2010). It involves the deliberate analysis of prior knowledge, current knowledge, the connection between those two aspects and the gaps in one's own understanding. The coherent connection between metacognition and the writing process has been documented throughout history. Vygotsky believed that writing involved the calculated analysis of one's own thoughts and comprehension and was vital in the monitoring of one's own learning (1987). Written works require the author to disseminate between the pertinent information of their inner speech and the variety of extraneous thoughts, in order to maximize understanding, thus making

necessary the, "deliberate structuring of a web of meaning forming associations between current and new knowledge" (Pugalee, 2001, p. 2). Based upon this belief of Vygotsky and various other researchers, writing is a generative act in the process of constructing meaning (Vygotsky, 1985; Maimon, Nodine, & O'Connor, 1989; NCTM 1999 & 2000). This construction of meaning, through the development of writing and thought are a critical aspect in the development of metacognition. Without providing students with the time and space to write, one is preventing them from fully appreciating the content they are learning and truly assessing their own understanding and growth.

This monitoring of one's own comprehension and thought processes is the epitome of becoming a successful problem solver and analytical mathematician. The problem solving processes of predicting, planning, attempting, revising, checking, guessing, and clarifying are the same processes applied by students when they evaluate their comprehension. Metacognition appears to implement itself as a vital component determining successful problem solving through its ability to allow an individual to identify and work strategically (Davidson & Sternberg, 1998). Pugalee performed a study on twenty ninth-grade algebra students, who were asked to provide written descriptions of their problem solving processes during their mathematics class. Pugalee's results suggested, students' writing samples demonstrated the incorporation of a multitude of metacognitive behaviors during initial reading, planning, execution, and verification phases of mathematical problem solving. The findings of his study underscore the importance of implementing a writing program in the mathematics classroom as an integral portion of developing students' self awareness and problem solving capabilities (1997).

The employment of writing in a mathematics curriculum fosters a reflective behavior, which is associated with deeper cognitive functioning. It is the intention of all learners to develop a personal connection to the material and an inner motivation to master content. These

metacognitive behaviors are generally grouped into two categories self-assessment and self-management (Rivers, 2001). Successful learners work to employ a wide variety of metacognitive skills from within these two categories and teachers are to facilitate the development of these skills. It is likely that the implementation of writing tasks within a mathematics classroom will contain metacognitive processes either by student motivation or teacher structuring, therefore in order to develop a greater mathematical literacy and comprehension writing prompts or free writes should become a regular practice within all mathematics classrooms. These writing to learn activities force students to clarify their thoughts, provide individualized and powerful feedback on their progress, focuses attention and helps students to identify knowledge they know and that of which they are unsure (Peery, 2005).

In 2004, the Mathematics Association of America's [MAA] Committee on the Undergraduate Program in Mathematics [CUPM] restructured their curriculum guide and made an addition which requires collegiate level mathematics programs to incorporate at least two writing activities which would help students increase their analytical, critical reasoning, problem-solving, and communication skills, while acquiring stronger mathematical abilities (Barker, Bressoud, Epp, Ganter, Haver, & Polatsek, 2004). Inspired by these new collegiate requirements, Ann, an introductory college mathematics instructor, redesigned two of her mathematics course such that throughout the semester students would be expected to participate in writing activities, which included but were not limited to free writing journal responses, prompted writings and mathematical biographies (Seto & Meel, 2006). At the end of the semester Ann reevaluated her course and the students success rate, and discovered the writing prompts helped her to become a more reflective and responsive practitioner, her students responded positively claiming they became much more aware of what they did and did not understand, furthermore students progressed to the next level of mathematics with resounding success in future courses (Seto & Meel, 2006).

The question remains then, why is writing a major component of post-secondary education, state and national standards, but still vastly overlooked in primary and secondary education? In fact a recent survey conducted by NCTM of 117 teachers, found that less than fifty percent of practicing teachers surveyed had never utilized writing in their mathematics classrooms (NCTM, 1999). Could classroom teachers be reluctant to incorporate writing in their curriculum due to the lack of direction on how to implement a writing program? Or is there fear of an overwhelming time commitment tied to writing tasks? Mathematical journals may just be the solution teachers and the educational system are looking for. According the Merriam-Webster Dictionary Online, a journal is, "a record of experiences, ideas or reflections kept regularly for private use" (2010). However, the private use of journals in education may be debated, and educators have thus created their own working definition of learning journals; writing that focuses on ongoing issues and topics over an extended period of time, with the intention of learning and marking learning progress (Liuliene, Metiuniene, 2009). Under this definition a journal becomes more than a daily log of events or diary of emotions.

Yet even with a working definition, the implementation of learning journals is quite vague. Whited suggests five types of journals: (1) a reflective journal, reflection on action, (2) a speculation about effects journal, reflection for action, (3) a double entry journal, (4) a metacognition journal, writing for one's own thinking and learning, and (5) a synthesis journal, application of what was learned (2005). It is highly likely that one writing task or journal would fulfill more than one of these purposes, yet each has the potential effect of pushing students to a high level of thought, deeper learning and metacognitive behaviors. Journaling activities promote a deeper learning through the encouragement of independent learning, providing a focusing point or an opportunity to gather one's thoughts as a means to see the whole system, the bigger picture, and finally provides an outlet for one to cope with and organize the copious amounts of information one processes on a daily basis (Moon, 1999). All of these positive

benefits of journaling are made possible by the positive and favorable learning space that they provide students. Journals create a self-contained learning space that accentuates a freeness for students to draft ideas, edit, revise and reorganize their thoughts into coherent learning outcomes (Moon, 1999). The reduction in affective filters offered by journals prompt students to become more engaged in their learning and less censured in their thoughts as the journal does not have to be shared with all classmates or any classmates for that case. This reduction in stress related with participating, and the ownership journals promote among students creates an increased motivation for students to actively reflect on and revise their mathematical comprehension (Burns, 2001).

The benefits of journaling in mathematics are not limited to student achievement and ownership of learning; teachers also gain advantage from the journaling of their students. Student responses provide advanced insight into the comprehension of a curriculum topic as well as gaps in understanding. This vital information allows teachers to adjust instructional practices and plans so as to achieve a high percentage of students at mastery of a topic or skill (Seto & Meel, 2006). The ramifications of the personalized insight into each student's comprehension and learning patterns offered by journaling has vast instructional implications, that when utilized by classroom teachers can greatly increase student achievement and problem-solving success.

Writing has the potential to challenge students to organize their thoughts and evaluate their learning. When implemented in a mathematics curriculum, writing opens the door to an increase in metacognitive functioning and advancement of strategic problem solving, however the lack of research and data to support these implications have prevented educators across the nation from reaping the benefits. It is the purpose of this study to provide insight into the procedure of journal writing in a mathematics classroom as well as study the influence of journal writing on the academic achievement of all students.

Project Design

In order to accomplish these goals the study was implemented in the following context. The study was conducted in a large suburban middle school, with a total enrollment of 1203 students in grades six through eight, of which 415 are eighth grade students. The average class size is 23 students with mathematics classes falling just under at an average class size of 21. Demographics of the school show 96% of the students are White, 1% are Black or African American, 1% are Hispanic or Latino, and 1% are Asian or Native Hawaiian or Other Pacific Islander. Of the total student population 4% qualify for a reduced lunch program and 2% qualify for a free lunch program. Performance results on New York State Standardized Tests in mathematics yield a 94% mastery rate for grade eight students, while 99% of the eighth grade students scored a two or higher (New York State Department of Education School Report Card, 2009).

The participants in this study consist of four eighth grade students, of which three are male and one is female; Mason, Rachel, Norm and Brian. Each student represents a different subset of student ability, based upon standardized test results and in class performance. All participants voluntarily elected to take part in the study. All names have been changed to protect the identities of individuals who participated in the study. Each student's primary caregivers were secondary participants in the study.

Mason is a 13 year and 10 month old, white, male. He comes from a stable two-parent home, wherein both parents work in professional fields, his mother is a teacher in another district and his father is vice-president of a technology research firm. Mason is small for his age and has many friends in his class. He averages a level three on the New York State Mathematics Assessments.

Rachel is a 13 year and 3 month old, white, female. She comes from a single parent household, where her mother is her sole caregiver. Rachel is of average size for her age and has many friends in her class. She averages a level 2 on the New York State Mathematics Assessments and receives the following testing modification: extended time (1.5x), directions clarified, test administered with minimal distractions, and check for understanding.

Norm is a 13 year and 9 month old, white, male. He comes from a stable two-parent household, wherein his father is a meat cutter and his mother is a surgical technician. Norm is of above average stature for his age and has a small group of friends in his class. He averages a level 3 on the New York State Mathematics Assessments and receives the following testing accommodations: extended time (1.5x).

Brian is a 13 year and 5 month old, white, male. He comes from a stable two-parent household, wherein his father is a police officer and his mother is a manager. Brian is of below average stature for his age and has many friends in his class. He averages a level 3 on the New York State Mathematics Assessments.

Procedures

The procedures administered during this study included whole class mini-lesson instruction, guided practice, independent practice and a variety of prompted and unprompted writing activities about the mathematical content.

Each day's instruction began with a whole class mini-lesson of the mathematical skills and content being covered at that time. During which time the researcher lead investigations/ explorations of the desired content strand, followed by the completion of guided notes lead by the participation of the students. The researcher would then model the application of the content strand while utilizing student input as they completed guided practice questions. This section of

the lesson was provided through the use of a ceiling mounted projector and animated notes created in Microsoft PowerPoint. Students would record their notes in a flip file (See Appendix A). Each day's guided notes and practice would then be followed by independent or partner application of the newly taught skill. Lessons would culminate in a journal writing activity. These activities included prompted responses to: procedural descriptions and processes; self refection and analysis of learning; as well as free write opportunities in which students could write about any remaining questions or ambiguities. For a list of the content strands covered and journal prompts utilized during this study please see Appendix B & C.

The classroom layout varied between three different floor plans. In the first floor plan, utilized 65% of the time, student desks were arranged in chunked rows of two to four desks lined up side by side with three rows deep from the front board. The second floor plan, utilized 35% of the time consisted of eight tables, each created from the grouping of three student desks together. For a complete diagram of each floor plan please see Appendix D.

Data Collection

This study was conducted from October 27th through December 3rd. Data sources were collected in the following six manners: student journal artifacts, pre and post tests for each content strand, student surveys and questionnaires, parent surveys and questionnaires as well as researcher anecdotal notes.

The student journals were created from multiple sheets of paper, folded in half and stapled together. The cover was constructed from green card stock paper and the front was decorated with math images as well as a space for the student's name and class period. The back cover was also decorated with a variety of content related math comics (See Appendix A). Each page provided a student work space at the top third of the page. Followed by lined writing space for the remaining two-thirds of the page. At the bottom of each page were three rating qualifiers:

(1) Back to the Drawing Board, (2) Proficient, and (3) Master. These qualifications allowed quick and prompt response by which students could judge their overall understanding and progress. In addition to the quick response qualifiers, the researcher also fully corrected any math work in the student work space as well as added comments specific to the students' responses, in order to prompt further discussion, further investigation on part of the student or to illuminate any drastic misunderstandings. These comments took the form of a student to teacher conversation. The student journals were collected for researcher evaluation each Wednesday and Friday. On average there were two to three full responses per week by the students.

A pretest for each content strand was administered prior to content instruction as well as prior to journaling activities. At the culmination of the content strand instruction a posttest was also administered. These pre- and post- tests took the form of a standardized mathematics assessment created by the researcher as a means of measuring student comprehension and growth in knowledge.

Student surveys utilized in this study, measured student response to journaling as well as self-evaluation of the influence of journaling on their mathematical understanding. The survey was administered at three separate times throughout the study: (1) prior to participating in any journaling activity and prior to receiving their journals, (2) the midpoint of the study, and (3) at the culmination of the study. The survey was accessed through the researcher's teacher website. All participants had web access from home and/or school. The survey results were then compiled for all five participants.

Parent surveys utilized in this study, measured parental response and evaluation of their respective student's growth and overall understanding of the content strands. This survey was also administered at three separate times throughout the study: (1) prior to participating in any journaling activity and prior to receiving their journals, (2) the midpoint of the study, and (3) at

the culmination of the study. The survey was accessed through the researcher's teacher website. All participants had access from home and/or school. The survey results were then compiled for all participants.

Data Analysis Procedures

The data collected during this study was processed through a variety of analysis procedures including, holistic rubric scoring of each student's journal responses (See Appendix E), tallying of parent and student survey responses and comparison of notable changes of response over the course of the study as well as comparison of students' pre and post test results, each graded based on the number of correct responses.

The four point, content writing, holistic rubric utilized in the scoring of each journal response evaluated the student's writing based upon the following eight desired characteristics: (1) Clearness of Subject/ Topic; (2) Focus; (3) Organizational Structure; (4) Elaboration; (5) Logical Progression; (6) Details Specific to the Development of the Topic; (7) Skillful use of Grade Level Appropriate Vocabulary; and (8) Sentence Fluency. Each journal response was read and then compared to each criterion statement in order to equate it to a holistic rating. The score for each of the eight criterions were then averaged to assign a single score to the overall journal response. Scores could range from zero to four points.

When assigning a criterion rating for the skillful use of grade level appropriate vocabulary the following two factors were considered, quantity of vocabulary included, and quality of vocabulary utilized. The vocabulary terms utilized in the response were recorded on the rubric itself. While the number of vocabulary terms required for each response varied, there were set minimum standards for the vocabulary usage which would constitute a rating of three, signifying proficiency in the topic. Responses utilizing more than the minimum vocabulary, received a rating of four, signifying mastery of the topic. Quality of vocabulary employed was

rated based upon a comparison to the New York State Mathematics Grade 8 curriculum guide. Responses containing vocabulary from the aforementioned list received a rating of four, signifying mastery. Reponses that utilized vocabulary from the two previous grade levels, six and seven, received a rating of three signifying proficiency. Vocabulary usage from grades prior to sixth were rated either two or one. For example, the usage of sum versus add elicited a rating of three or four rather than a score of one or two. Additionally, the use of multiplicative inverse as opposed to multiply by or divide by earned a higher rating.

The parent and student survey responses were compiled on a duplicate copy of the surveys. Tally marks signified each participant's responses. The numbers of responses per category were then compared between the initial surveys, midpoint surveys, and final surveys. Changes in responses, either an increase in agreement or decreases in agreement, were cited.

The pre- and post-tests were graded based on the number of correct responses. Pre-test scores were then compared to post-test scores. The percent of change was then calculated for each pre- and post-test pair. Percent of change was determined as follows, the difference in scores from the post-test and pre-test was found, then the quotient of that value and the pre-test score was tabulated, and then the product of that value and one hundred was calculated. This final term, expressed as a percentage, represented the amount of improvement, or lack of improvement.

At the end of each content unit, each participating student received five scores, three of which were journal ratings, two being the pre- and post test scores, and then anecdotal notes. All scores were recorded in the participants' files.

Results

From the data that was collected, four mini-cases of students were created. Students' names were changed to ensure anonymity.

Mason is a 13 year and 10 month old, white, male. He comes from a stable two-parent home, wherein both parents work in professional fields, his mother is a teacher in another district and his father is vice-president of a technology research firm. Mason is small for his age and has many friends in his class. He averages a level three on the New York State Mathematics Assessments.

Initially Mason was achieving an 83% grade point average in mathematics. He reported being "unsure" when attempting to solve math problems, but said he enjoyed math. Mason also reported a neutral feeling of confidence when explaining his mathematical thinking in class. His initial opinions about writing suggest a mild support of the belief that writing will improve his mathematical abilities. He found it challenging to express all details contained in his procedures and was neutral in his feelings about writing in a math journal. However, he supported the idea that writing about nonfiction is important to the development of a student. His initial survey results indicated a mild support for the implementation and possible positive influence of journaling in mathematics.

By the midpoint of the study, Mason was maintaining an 83% grade point average, however his survey results indicated a stronger positive opinion of the benefits of journaling in mathematics. He reported feeling more confident when explaining procedural steps in class as well as an overall gain in mathematical problem solving skills.

At the culmination of the study Mason was achieving an 86% grade point average in mathematics and his survey results indicated a stronger positive opinion of the benefits of writing

in mathematics. He responded, "strongly agree" when responding to the statement, "I feel confident when explaining my steps in math class." Furthermore he also responded, "strongly agree" when responding to the statement, "You can better understand how to solve math problems by writing about them." For a complete inventory of responses to each of the surveys please see Apendix F.

These survey results are mirrored in the responses provided my Mason's guardian in the parent survey. The initial results of the parent survey suggested a mild support for the positive influence of journaling in mathematics and a "struggles" to "average" rating, depending on the content, when considering their child's mathematical abilities. By the midpoint of the study the parent survey indicated strong support of the implementation of journaling in mathematics and an "average" ability rating for their child's mathematical skills. At the culmination of the study the parent survey continued to indicate strong support for the implementation of journaling, with "strongly agree" responses across the board. Furthermore the parents indicated an increase in their child's mathematical abilities from "average" to "average/excels." For a complete inventory of responses to the parent surveys please see Appendix G.

Mason's journal entries ranged in score from 2.7 to 4 points, based on the holistic content writing rubric utilized in analysis (Appendix E).

Mason's journal entry scores as well as pre- and post-test results can be found in the table below, sorted by content strand.

Content Strand	Journal Entry Scores	Pre-Test	Pre-Test	Percent Increase
Solving Multi-Step Equations	3, 3.5, 4	90%	100%	11.1%
Percent Applications	2.7, 2.9, 3	82%	86%	4.9%
Exponents	2.9, 3, 3.3	82%	90%	9.8%
Angles & Lines	3, 3.2, 4	80%	92%	15%

Within the researcher's anecdotal notes an increase in class participation, and overall confidence in mathematical abilities were also observed. Previous to the study Mason would participate once or twice at most during class discussions. At the end of the study Mason was raising his hand at 90% of the posed questions and answered at least six questions per class.

Rachel is a 13 year and 3 month old, white, female. She comes from a single parent household, where her mother is her sole caregiver. Rachel is of average size for her age and has many friends in her class. She averages a level 2 on the New York State Mathematics Assessments and receives the following testing modification: extended time (1.5x), directions clarified, test administered with minimal distractions, and check for understanding.

Initially, Rachel was achieving a 76% grade point average in mathematics. She reported being "unsure" when attempting to solve math problems, but said she enjoyed math. She also reported a neutral feeling of confidence when explaining her mathematical thinking in class. Her initial opinions about writing suggest a strong enjoyment of writing but a mild support of the belief that writing will improve her mathematical abilities. She found it challenging to express all details contained in her procedures but was positive in her feelings about writing in a math journal. She supported the idea that writing about nonfiction is important to the development of a student. Her initial survey results indicated a strong enjoyment of writing, but mild to neutral support for the implementation and possible positive influence of journaling in mathematics.

At the midpoint of the study, Rachel agreed that writing about mathematics was helping her to understand mathematics better, and was achieving a 78% grade point average. Rachel's survey results also indicated a greater ease at including all necessary details when writing about her problem solving processes as well as a better understanding of problem solving procedures.

At the culmination of the study, Rachel was maintaining a 78% grade point average in mathematics and her survey results indicated a stronger positive opinion of the benefits of

writing in mathematics. She responded, "strongly agree" when responding to the statement, "I enjoy writing in a math journal." Furthermore she also responded, "strongly agree" to the statement, "I think writing about math will help me to understand math better." For a complete inventory of the survey results please see Appendix F.

Initially the possible positive impact of journaling in mathematics was met with more skepticism by Rachel's guardian, whom responded "neutral" to each of the following statements, "It is important that my child write about concepts in the content areas," and, "I believe writing about her mathematical procedures utilized in solving problems will improve my child's mathematical problem solving." The parent survey also indicated Rachel's mathematics abilities as "struggles;" however, Rachel's parent survey did indicate a strong enjoyment of writing by Rachel as well. By the midpoint of the study, the parent survey indicated a strong support of the implementation of journaling in mathematics and an average ability rating for Rachel. At the end of the study, the parent survey continued to support the implementation of journaling in mathematics, with "strongly agree" responses to each of the following statements, "It is important that my child write about concepts in the content areas," and, "I believe writing about her mathematical procedures utilized in solving problems will improve my child's mathematical problem solving." For a complete inventory of responses to the parent survey please see Appendix G

Rachel's journal entries ranged in score from 2 to 3.9 points, based on the holistic content writing rubric utilized in analysis (See Appendix E).

Rachel's journal entry scores as well as pre- and post-test results can be found in the table on the subsequent page.

Content Strand	Journal Entry Scores	Pre-Test	Pre-Test	Percent Increase
Solving Multi-Step Equations	3, 3.2, 3.6	90%	91%	1.1%
Percent Applications	2.1, 3, 3.8	61%	80%	31.1%
Exponents	2, 2.6, 3.9	56%	70%	25%
Angles & Lines	3, 3.2, 3.3	90%	100%	11.1%

Within the researcher's anecdotal notes an increase in class participation and overall confidence in mathematical abilities were also observed. Previous to the study Rachel would voluntarily participate very rarely during class discussions and sat near the back of the room. At the end of the study Rachel was selecting seats near the front of the room, within close proximity to the instructor and participating at least three times during class.

Norm is a 13 year and 9 month old, white, male. He comes from a stable two-parent household, wherein his father is a meat cutter and his mother is a surgical technician. Norm is of above average stature for his age and has a small group of friends in his class. He averages a level 3 on the New York State Mathematics Assessments and receives the following testing accommodations: extended time (1.5x).

Initially Norm was achieving a 65% grade point average in mathematics. He reported being "unsure" when attempting to solve math problems, but said he enjoyed math. Norm also reported an average feeling of confidence when explaining his mathematical thinking in class. His initial opinions about writing indicate a neutral support of the belief that writing will improve his mathematical abilities. He found it challenging to express all details contained in his procedures and was reluctant in his feelings about writing in a math journal. However, he supported the idea that writing about nonfiction is important to the development of a student.

His initial survey results fell into a range between neutrality and disagreement in support for the implementation and possible positive influence of journaling in mathematics.

By the midpoint of the study, Norm was maintaining a 67% grade point average, however his survey results indicated a stronger positive opinion of the benefits of journaling in mathematics. He reported continued confidence when explaining procedural steps in class as well as an overall gain in mathematical problem solving skills.

At the culmination of the study Norm was achieving a 70% grade point average in mathematics and his survey results indicated a continual positive opinion of the benefits of writing in mathematics. He responded, "agree" when responding to the statement, "I feel confident when explaining my steps in math class." Furthermore he also responded, "agree" when responding to the statement, "You can better understand how to solve math problems by writing about them." For a complete inventory of responses to each of the surveys please see Appendix F.

These survey results are mirrored in the responses provided my Norm's guardian in the parent survey. The initial results of the parent survey suggested a neutral support for the positive influence of journaling in mathematics and a "struggles" rating, when considering their child's mathematical abilities. The parent survey also cited a dislike of writing by Norm. By the midpoint of the study the parent survey indicated strong support of the implementation of journaling in mathematics and a "struggles/average" ability rating for their child's mathematical skills. At the culmination of the study the parent survey continued to indicate strong support for the implementation of journaling, with "strongly agree" responses across the board. Further more the parents indicated an increase in their child's mathematical abilities from "struggles/average" to "average." For a complete inventory of responses to the parent surveys please see appendix G.

Norm's journal entries ranged in score from 3 to 4 points, based on the holistic content writing rubric utilized in analysis (Appendix E).

Norm's journal entry scores as well as pre- and post-test results can be found in the table below, sorted by content strand.

Content Strand	Journal Entry Scores	Pre-Test	Pre-Test	Percent Increase
Solving Multi-Step Equations	3, 3.5, 3.5	80%	85%	6.3%
Percent Applications	3, 2.9, 3.8	75%	80%	6.7%
Exponents	2.9, 4, 3.3	74%	74%	0%
Angles & Lines	3, 3, 4	80%	90%	12.5%

Within the researcher's anecdotal notes an increase in class participation, and overall confidence in mathematical abilities were also observed. Previous to the study Norm would participate once or twice at most during class discussions and most often his answers were posed more as questions then direct answers. At the end of the study Norm was raising his hand at 50% of the posed questions and answered at least three questions per class with confidence.

Brian is a 13 year and 5 month old, white, male. He comes from a stable two-parent household, wherein his father is a police officer and his mother is a manager. Brian is of below average stature for his age and has many friends in his class. He averages a level 3 on the New York State Mathematics Assessments.

Initially Brian was achieving an 85% grade point average in mathematics. He reported being "average/confident" when attempting to solve math problems, and said he enjoyed math. Brian also reported a neutral feeling of confidence when explaining his mathematical thinking in class. His initial opinions about writing indicate support of the belief that writing will improve

his mathematical abilities. He found it challenging to express all details contained in his procedures but expressed enjoyment of writing in a math journal. Brian also supported the idea that writing about nonfiction is important to the development of a student. His initial survey results indicated a support for the implementation and possible positive influence of journaling in mathematics.

By the midpoint of the study, Brian was achieving an 86% grade point average, however his survey results indicated a stronger positive opinion of the benefits of journaling in mathematics. He reported feeling more confident when explaining procedural steps in class as well as an overall gain in mathematical problem solving skills.

At the culmination of the study Brian was achieving an 89% grade point average in mathematics and his survey results indicated a stronger positive opinion of the benefits of writing in mathematics. He responded, "strongly agree" when responding to the statement, "I feel confident when explaining my steps in math class." He also responded, "strongly agree" when responding to the statement, "You can better understand how to solve math problems by writing about them." For a complete inventory of responses to each of the surveys please see Appendix F.

These survey results are mirrored in the responses provided my Brian's guardian in the parent survey. However, the initial results of the parent survey indicated a neutral support for the positive influence of journaling in mathematics and a "struggles" to "average" rating, when considering their child's mathematical abilities; as well as a strong dislike of writing by Brian. By the midpoint of the study the parent survey indicated strong support of the implementation of journaling in mathematics and an "average" ability rating for their child's mathematical skills. At the culmination of the study the parent survey continues to indicate strong support for the implementation of journaling, with "strongly agree" responses across the board. Furthermore the

parents indicated an increase in their child's mathematical abilities from "average" to "average/excels." For a complete inventory of responses to the parent surveys please see Appendix G.

Brian's journal entries ranged in score from 3.2 to 4 points, based on the holistic content writing rubric utilized in analysis (Appendix E).

Brian's journal entry scores as well as pre- and post-test results can be found in the table on the subsequent page, sorted by content strand.

Content Strand	Journal Entry Scores	Pre-Test	Pre-Test	Percent Increase
Solving Multi-Step Equations	3.2, 3.3, 3.6	95%	97%	2.1%
Percent Applications	3, 3, 3.6	72%	100%	25%
Exponents	3, 3, 3.3	76%	76%	0%
Angles & Lines	3.6, 3.2, 4	80%	100%	25%

Within the researcher's anecdotal notes an increase in class participation, and overall confidence in mathematical abilities were also observed. Previous to the study Brian would participate regularly during class discussions, however, most responses were marked with a lack of confidence. At the end of the study Brian was continuing to raise his hand at least 80% of the time and was answering with complete confidence.

Limitations

During this study it became apparent that there are certain procedural and material realities that placed confines on the data gathered. One limitation in the data collection is the design of the student survey. Since the students were reflecting on their own abilities and confidences the results didn't necessarily reflect their true abilities. This could be a product of

their desire to please authority figures, which caused them to answer as the researcher would want them to respond. Another possible source of error in the survey results may have been their distorted self-perceptions. Middle school students tend to over-estimate their abilities whether it be academically, socially or physically.

Another limitation in research was the design of the math journals. Due to allotment of workspace for the means of problem solving, the writing space was limited to two-thirds of the page. This limited the student responses as they felt uncomfortable expanding onto the next page to continue their responses and contributed to an overall lack of elaboration in the journal responses. In future replications of this study the use of marble writing notebooks may work to better serve the purpose of journaling space. The lines work space would allow for orderly mathematical work as well as unlimited writing space as students would feel more comfortable continuing to the next page as they do in English Language Arts as well as previous writing courses.

Conclusions/ Implications

The purpose of this study was to determine the influence of content writing tasks on mathematics achievement of middle school students, as well as study the influence of math journals as the media in which to implement content writing activities. Through the use of pre- and post-test content assessments, student and parent surveys as well as a holistic content writing evaluation rubric, content writing tasks can influence the mathematical achievement of students. Furthermore the use of a math journal provided a suitable and comfortable media in which these writing tasks could be completed. While the other instructional activities that were taking place in the classroom during the context of this study certainly played a role in determining the students' overall mathematical achievement, the influence of the content writing tasks cannot be discounted.

It is my belief that the content writing tasks were effective for a variety of reasons. First, the writing tasks asked to students to revisit and reflect upon the content being studied. This forced students to reference their math content notes, retrieve previous content knowledge and then synthesize a response from those two realms of knowledge. The synthesis of the two knowledge sources into a single response causes the brain to increase the complexity of connections to knowledge; which further cements the new content within the realm of retrievable knowledge while attaching to the previous knowledge in a second location, thus creating greater context associations. These context associations are the means for greater knowledge accumulation and higher success rate of knowledge retrieval (Vygotsky, 1987).

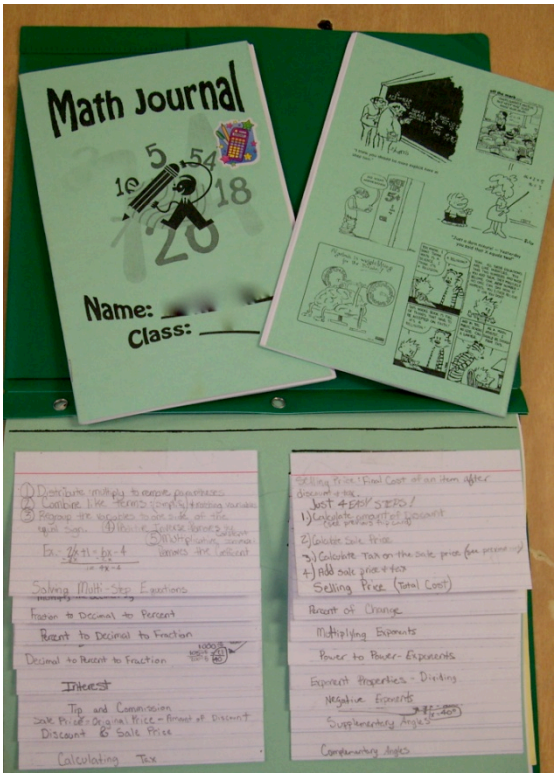
Secondly, content writing activities foster metacognitive development in either of two areas, self-reflection, or self-assessment. As students work to develop these two tracks of thought they develop and achieve deeper cognitive functioning (Rivers, 2001). The writing activities force students to clarify their thoughts as well as reorganize their progression of problem solving and identify gaps in their understanding. Student responses to content writing prompts provide powerful information for students and teachers alike. In reading through a written response it becomes ever more evident when a confusion or gap in understanding exists, which allows for students to revisit their class notes for clarification, ask the instructor for clarification or for the instructor to adjust instruction so as to address these misunderstandings.

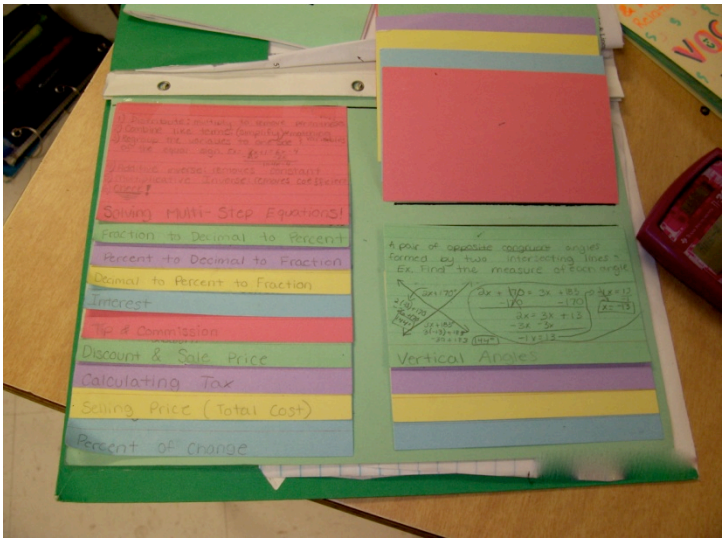
Finally, it is my belief that math journals do provide an effective media in which to conduct these content writing activities. Journals create a self-contained learning space, which provides students with an increased amount of freedom. Freedom allowing students to draft, edit and revise their responses so as to fully identify content strands they have mastered as well as those in which they require further study and reinforcement (Peery, 2005). This freedom further accentuates a reduction in affective filters. The anxiety of posing a question or answer in front of

their peers can limit a student's participation as well as depth of understanding. However, in a journaling situation students are free to pose questions draft solutions and identify areas of weakness within the content. This freedom also produces a greater level of student motivation to actively reflect upon their learning and to revise previously conceived theories. Each of these positive benefits of the implementations of math journals were cited by participants of the study as well as their parents.

Overall, the implementation of content writing tasks through the use of math journals had a favorable outcome in the view of students and parents alike. With the current trends in education focusing evermore on writing and a student's ability to formulate logical written responses to procedural problem solving situations, the use of content writing tasks can prove to be a positive influence on student's mathematical achievement. Furthermore, math journals provide an excellent media in which to perform these writing tasks for the amount of freedom they create for student response and interpretation.

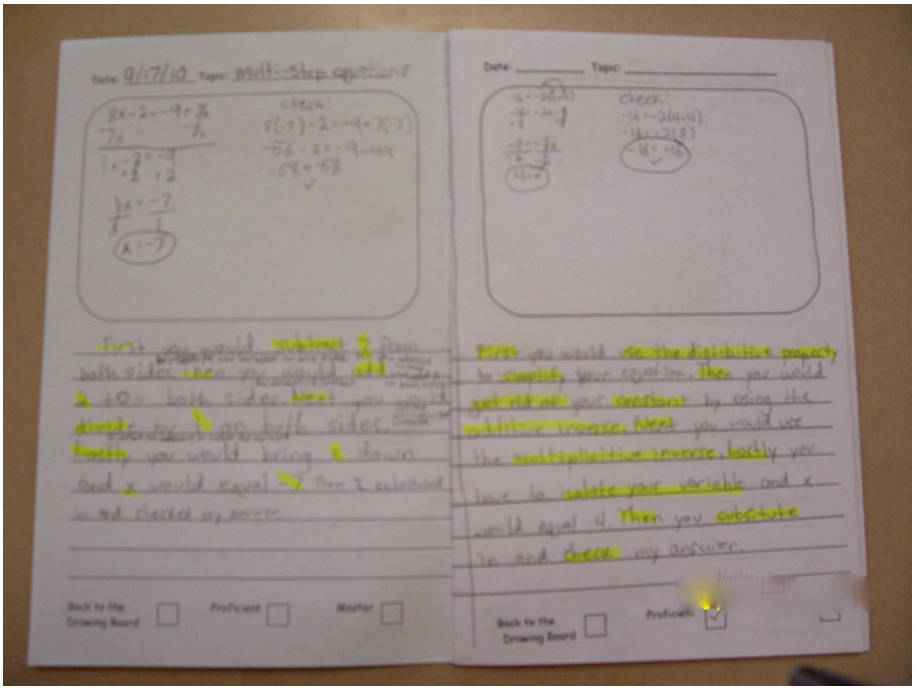
Appendix A





Math Flip File Notes

Math Flip File Notes with Math Journal



Math Journal Response Space

Appendix B The content strands covered during this study include:

- Ratios, Proportions & Percents
- Applications of Percents:
  - Discount
  - Sale Price
  - Tax
  - Final Cost
  - Interest
  - Tip & Commission
- Properties of Exponents
- Solving Multi-Step Equations
- Lines and Angles:
  - Supplementary
  - Complementary
  - Vertical
  - Alternate Exterior
  - Alternate Interior
  - Corresponding Angles
  - Transversal
  - Parallel Lines
  - Right Angles

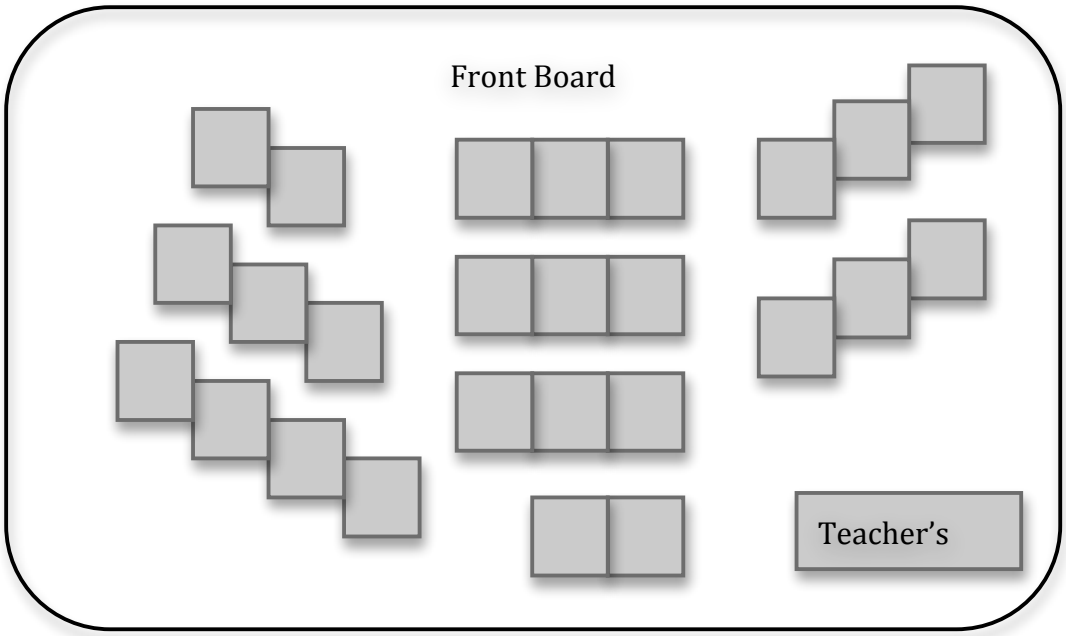
Appendix C: Prompted Journal Responses Included:

- Explain the process you would use to isolate the variable in the following equation: $2(x-5) = 3x + 20$
- Explain how the distributive property applies to equations.
- Describe the process you would follow in order to simplify the following exponential problems:
  - $N^x \times N^y$
  - $(N^x)^y$
  - $N^x \div N^y$
- What is a mortgage? Why would you need one?
- When comparing two loans, how would you decide which loan has the better terms?
- Describe the process used to calculate the final selling price of a discounted and taxed item.
- Today I learned….
- Two things I learned are…. One question I have is….
- What are parallel lines? Perpendicular lines? How are they similar? How are they different?
- What does it mean to be congruent? If you were redesigning your room with congruent items what would your room look like? Sketch a picture and describe your design choices.
- If it is 4 o'clock the arms of the clock form an obtuse angle. How could you figure out the number of degrees in that angle algebraically?
- What does it mean for two angles to be supplementary? How could you find the measure of each angle if you know the two are supplementary?

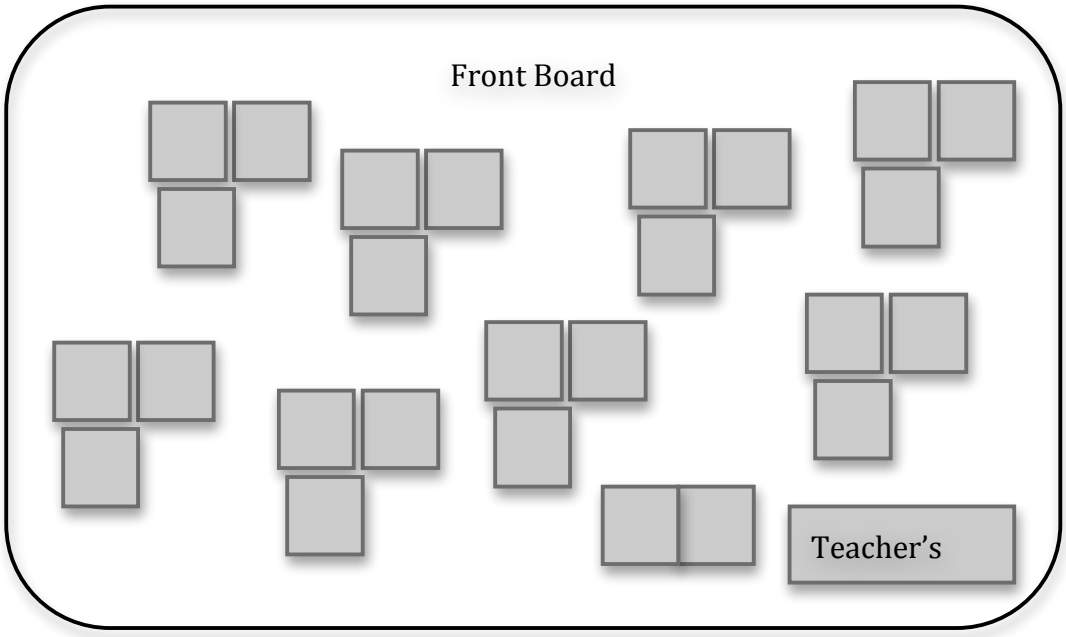
- What does it mean for two angles to be Complementary? How could you find the measure of each angle if you know the two are Complementary?
- Write a letter to someone describing what you learned in math today.
- Write an explanation of right angle, obtuse angle and acute angle that a first grader would understand.

Appendix D: Classroom Layouts

Layout 1



Layout 2



Appendix E: Holistic Content Writing Rubric

Points	Description
4	· Topic/subject is clear, though it may or may not be explicitly stated · Maintains focus on topic/subject throughout the response · Organizational structure establishes relationships between and among ideas and/or events · Consists of a logical progression of ideas and/or events and is unified and complete · Support and elaboration are related to and supportive of the topic/subject · Consists of specific, developed details · Exhibits skillful use of vocabulary that is precise and purposeful · Demonstrates skillful use of sentence fluency
3	· Topic/subject is generally clear, though it may or may not be explicitly stated · May exhibit minor lapses in focus on topic/subject · Organizational structure establishes relationships between and among ideas and/or events, although minor lapses may be present · Consists of a logical progression of ideas and/or events and is reasonably complete, although minor lapses may be present · Support and elaboration may have minor weaknesses in relatedness to and support of the topic/subject · Consists of some specific details · Exhibits reasonable use of vocabulary that is precise and purposeful · Demonstrates reasonable use of sentence fluency
2	· Topic/subject may be vague · May lose or may exhibit major lapses in focus on topic/subject · Organizational structure may establish little relationship between and among ideas and/or events · May have major lapses in the logical progression of ideas and/or events and is minimally complete · Support and elaboration may have major weaknesses in relatedness to and support of the topic/subject · Consists of general and/or undeveloped details, which may be presented in a list-like fashion · Exhibits minimal use of vocabulary that is precise and purposeful · Demonstrates minimal use of sentence fluency
1	· Topic/subject is unclear or confusing · May fail to establish focus on topic/subject · Organizational structure may not establish connection between and among ideas and/or events · May consist of ideas and/or events that are presented in a random fashion and is incomplete or confusing · Support and elaboration attempts to support the topic/subject but may be unrelated or confusing · Consists of sparse details · Lacks use of vocabulary that is precise and purposeful · May not demonstrate sentence fluency
NS	· This code may be used for compositions that are entirely illegible or otherwise unscorable: blank responses, responses written in a foreign language, restatements of the prompt, and responses that are off-topic or incoherent.

Appendix F: Student Survey Results

		I feel confident when explaining my steps in math class.	I think writing about math will help me to understand math better.	I include all details necessary when writing about a math process.	I enjoy writing in math journal.	Writing about nonfiction process is important to developing as a student.	You can better understand how to solve math problems by writing about them.
Completely Disagree	**Initial**	0%	0%	0%	0%	0%	0%
	Midpoint	0%	0%	0%	0%	0%	0%
	Final	0%	0%	0%	0%	0%	0%
Disagree	**Initial**	0%	0%	0%	0%	0%	0%
	Midpoint	0%	0%	0%	0%	0%	0%
	Final	0%	0%	0%	0%	0%	0%
Neutral	**Initial**	50%	100%	100%	75%	100%	75%
	Midpoint	25%	50%	25%	50%	0%	0%
	Final	0%	0%	0%	0%	0%	0%
Agree	**Initial**	50%	0%	0%	25%	0%	25%
	Midpoint	75%	50%	75%	50%	100%	50%
	Final	50%	25%	25%	0%	0%	0%
Strongly Agree	**Initial**	0%	0%	0%	0%	0%	0%
	Midpoint	0%	0%	0%	0%	0%	50%
	Final	50%	75%	75%	100%	100%	100%

Appendix G: Parent Survey Results

		It is important to me that my child writes about concepts in the content areas.	I believe writing about hi/her mathematical procedures utilized in solving problems, will improve my child's mathematical problem solving.	I ask my son/daughter to tell me about math topics he/she is currently studying regularly.	My child enjoys writing.	My child enjoys math.	My child can explain math concepts to me thoroughly.
Completely Disagree	**Initial**	0%	0%	0%	25%	0%	0%
	Midpoint	0%	0%	0%	0%	0%	0%
	Final	0%	0%	0%	0%	0%	0%
Disagree	**Initial**	0%	0%	0%	25%	0%	0%
	Midpoint	0%	0%	0%	0%	0%	0%
	Final	0%	0%	0%	0%	0%	0%
Neutral	**Initial**	75%	100%	100%	0%	100%	75%
	Midpoint	0%	50%	75%	25%	100%	50%
	Final	0%	0%	0%	0%	0%	0%
Agree	**Initial**	25%	0%	0%	0%	0%	25%
	Midpoint	50%	50%	0%	25%	0%	50%
	Final	25%	25%	50%	25%	100%	0%
Strongly Agree	**Initial**	0%	0%	0%	50%	0%	0%
	Midpoint	50%	0%	25%	50%	0%	0%
	Final	75%	75%	50%	75%	0%	100%

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