

Writing and Reading in Mathematics

by

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A Research Paper  
Submitted in Partial Fulfillment of the  
Requirements for the  
Master of Science Degree in

Education

Approved: 2 Semester Credits



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July 6, 2008

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**Title: *Writing and Reading in Mathematics***

**Graduate Degree/Major: MS Education**

**Research Adviser: Jim Lehmann**

**Month/Year: July 30, 2008**

**Number of Pages: 56**

**Style Manual Used: American Psychological Association, 5<sup>th</sup> edition**

**ABSTRACT**

The purpose of this study is to investigate and determine the effectiveness of teaching students writing and reading in mathematics. The study contains an extended review and analysis of research literature related to teaching students mathematics through reading and writing. Conclusions and recommendations were made accordingly to provide information to 8<sup>th</sup> grade Mathematics teachers on how to improve their teaching and raise students' standardized test scores.

This study will help mathematics teachers to explore new methods in teaching of reading and writing in mathematics to 8<sup>th</sup> grade students, and to practice constructivism learning, which includes methods of investigation, reasoning, and communication.

According to the National Council of Teachers of Mathematics (NCTM) standards of mathematics, students are expected to be proficient in communicating mathematics. Even

though teachers currently cover the NCTM standards, test scores still show poor performance in the area of mathematics communication across the country. Mathematics teachers must therefore become more efficient in relating this subject to their students.

Teachers should emphasize the terms and symbols required for their students to grasp mathematical concepts, including equations, and to analytically conceptualize the problems they are required to solve. Mathematicians choose their words carefully to communicate each concept clearly and concisely, and therefore their students should be able to do the same. This investigation will evaluate methods of instruction to apply in the classroom that will include writing and reading activities in mathematics. From this study, teachers will be presented with options of approach to choose in presenting mathematics to their students. These options are designed for use within the classrooms to enhance students' knowledge and communication skills on mathematics.

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### Acknowledgments

I wish to express love and gratitude to my children Lonnie, Christopher and Sean, who encouraged and supported me throughout this project. Next, I would like to thank Dr. Jim Lehman for his support and guidance throughout the writing of this research.

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## Chapter I: Introduction

The issue of teaching reading and writing in mathematics classrooms continues to surface as one of the most challenging problems in education. This is particularly true as the performance of American students in primary and secondary level mathematics is consistently going down in comparison to their peers from other industrialized nations. In a new study conducted by the American Institutes for Research (AIR), released in November 2005, titled, “Reassessing US International Mathematics Performance: New Findings from the 2003 TIMSS and PISA,” it was found that:

Despite a widely held belief that U.S. students do well in mathematics in grade school but decline precipitously in high school, a new study comparing the math skills of students in industrialized nations finds that U.S. students in 4th and 8th grade perform consistently below most of their peers around the world and continue that trend into high school. (¶ 1)



The table below shows that the United Nations only ranked 9<sup>th</sup>:

Table 1

*Rankings of 12 Countries Participating on the 2003 International Mathematics Assessments: TIMSS Grades 4 and 8, and PISA Age 15*

Country	This New Analysis			Previous Analyses		
	Common Set of 12 Countries			Full set of 24	Full set of 45	Full set of 40
	TIMSS	TIMSS	PISA	TIMSS	TIMSS	PISA
	Grade 4	Grade 8	Age 15	Grade 4	Grade 8	Age 15
Hong Kong	1	1	1	2	3	1
Japan	2	2	3	3	5	6
Belgium	3	3	4	5	6	8
Netherlands	4	4	2	6	7	4
Latvia	5	6	9	7	11	27
Hungary	7	5	8	10	9	25
Russia	6	6	11	8	11	29
Australia	10	8	5	15	14	11
United States	8	9	9	11	15	27
New Zealand	11	10	6	16	20	12
Norway	12	12	7	20	27	22
Italy	9	11	12	14	22	31

Country rankings for common set of 12 countries are from highest score (equals 1) to lowest score (equals 12). Country rankings from previous analyses are from highest score (equals 1) to lowest score (equals 24 for TIMSS Grade 4, 45 for TIMSS Grade 8, and 40 for PISA).

Tunisia also participated in all three international results, but it is not an industrialized country and was omitted from our study.

Source: Mullis, Martin, Gonzalez, and Chrostowski, 2004; OECD, 2004.

While the performance of American students in mathematics is getting worse, the opposite is the case with reading and writing. According to a report by the National Research Council (NRC) in 2001, “United States schools have been relatively successful in developing

skilled reading, with improvements in both instruction and achievement occurring in a large number of schools” (p. 17). Burley-Allen (1982) reinforced this idea, saying “school students do not lack training in written communication, since on average they receive 12 school years of training in writing and 6-8 school years of training in reading” (p. 24).

Although American students are improving in reading and writing, some researchers believe that the same is not true with writing in mathematics. According to Morgan (1998):

The writing done in secondary schools mathematics classrooms has, until recently, been extremely restricted... While students have sometimes recorded, page after page of repetitive symbolic manipulations, their writing of verbal language has generally consisted of little more than a few isolated words. (p. 1)

Until recently, mathematics teachers have believed that writing should be taught in other classes while the teaching of how to manipulate numbers belongs in a math class. Teaching students to solve one step, or two step equations and the use of distributive property in Algebra can be worthless if students do not have a clear understanding of why they are performing these actions.

The history of education has given little attention to writing in mathematics. Davison and Pearce (1988) suggested that, “In spite of the greater influence of the Writing-to-Learn movement, neither the quantity nor the quality of writing used in the mathematics classrooms was substantial” (p. 10). Teachers taught straight computational work in the classroom and most of the time provided only one method for solving an equation. Part of the problem lies in the fact that the students, parents, and educators relate mathematics more to numbers or shapes than to writing. Morgan (1998) stated that, “The writing done in secondary school mathematics classrooms has, until recently, been extremely restricted” (p. 1). Thus, there exists a need to broaden both reading and writing in the mathematics classroom.

Frameworks of encouraging collaboration and interaction among students, as well as activities involving investigation and analysis, have been provided in overwhelming numbers by studies from educational psychologists like Dewey (1910), Bruner (1961), and Martinez and Martinez (2001). These studies have gone a long way to modernize education, and aimed to improve teaching and learning in education by stressing the role of reading and writing in the classroom. According to Martinez and Martinez (2001), “Reading and writing are essential to both develop problem-solving and concept discovery processes” (p. 1). These theorists stressed the need for using a variety of exploratory methods and technology to improve learning, also stressing the positive effect of using writing assignments in mathematics.

In his book, *Writing to Learn*, Zinsser stated, “Writing is a way to work yourself into a subject and make it your own” (1998, p. 24). Today there is a movement in education that encourages teachers to include writing activities in every subject as ways to reflect and organize thoughts. Zinsser (1998) also added that, “Clear writing is the logical arrangement of thought; a scientist who thinks clearly can write as well as the best writer” (p. 4). Including writing in mathematics classrooms necessitates a change in the way we think about mathematics.

The demands made on mathematics teachers are higher now, compared to some years ago, which make teaching of the subject more difficult. Morgan (1998) identified several important factors related to reading and writing during an evaluation of mathematics teachers. Morgan found that, in general, students were not producing writing in mathematics classes. There existed an assumption that mathematics is only about numbers, and mathematics teachers were not trained to teach writing. Additionally, mathematics curriculums often did not encourage teachers to use writing as a method in mathematics instruction (Morgan, 1998, p. 10).

All these factors have produced students who “are not successful at producing extend writing and that the requirement to write may prevent them from doing the mathematics” (Morgan, 1998, p. 10). One of the reasons for this is that teachers have to cover more material in less time, students have to take yearly standardized tests, and students have to take more mathematics classes to be able to graduate from high school. These factors may prevent educators from taking the time to teach writing in relationship to mathematics; thus limiting students to learning only isolated concepts by memorizing the steps.

### *Statement of the Problem*

Thinking about math is thinking about numbers, shapes or symbols. Math is rarely thought to be about producing writing, because writing has never been included in classes as an assessment tool to help students learn. Currently, one of the standards for the National Council of Teachers of Mathematics (NCTM) is communication. According to this standard, students should be able to:

1. Organize and consolidate their mathematical thinking.
2. Communicate their mathematical thinking coherently and clearly to peers, teachers, and others.
3. Analyze and evaluate the mathematical thinking and strategies of others.
4. Use the language of mathematics to express mathematical ideas precisely. (2008)

Students are learning isolated concepts in math classes mainly through procedures such as operations with numbers and algebraic algorithms. Writing is a valuable tool that can be used across the curriculum. It can enhance students understanding of mathematics by helping students to organize ideas, and to think about what it is being taught. Teachers that include this method in

their classrooms will be more successful in educating students in this subject. However, this concept has yet to be popularized so that more teachers will be able to adopt this approach.

### *Purpose of the Study*

The purpose of this study is to determine effectiveness of teaching reading and writing in mathematics, and how students can benefit from this approach. Based on the analysis of the research literature, this study has arrived at a conclusion and listed recommendations to increase the effectiveness of teaching mathematics through writing and reading.

### *Objectives*

The primary objective of this study is to establish the effectiveness of teaching reading and writing mathematics in relationship to the students' performance in the subject. This study will also describe how educational psychology has influenced educators in changing their methods of teaching mathematics. This study will additionally discuss the inclusion of reading and writing in the NCTM standards, and the importance of teaching communication. This study will also provide a discussion of teaching tools and instruments for assessments that educators can use in the classroom to enhance math understanding.

### *Definitions of Terms*

In order to provide a comprehensive understanding of the research in this study, the following definitions of terms are provided for the reader:

*National Council of Teachers of Mathematics (NCTM).* The National Council of Teachers of Mathematics is the public voice of mathematics education, providing vision, leadership, and professional development to support teachers in ensuring mathematics learning of the highest quality for all students.

*Mathematical Sciences Education Board (MSEB).* The Mathematical Sciences Education Board is a subsidiary of the National Research Council's Center for Education (CFE), which is tasked to provide guidance and national leadership on programs, practices and policies that would support the improvement of mathematics education across all levels.

*Trends in International Mathematics and Science Study (TIMSS).* The Trends in International Mathematics and Science Study provides data on the achievement scores of American students in math and science compared to other countries.

*Program for International Student Assessment (PISA).* The Program for International Student Assessment is a part of the Organization for Economic Co-operation and Development (OECD) program, designed to assess the performance of students from different countries.

#### *Limitations of the Study*

Students and teachers may react negatively if they are asked to write in mathematics classrooms. This is due to the fact that mathematics has always been related to numbers, symbols and shapes. Thus, not every teacher will be willing to use reading and writing assignments in the classroom, as they will not feel confident about teaching writing in a mathematics class. The conclusion and recommendations of this study will only apply to classrooms where teachers are willing to use these methods.

#### *Methodology*

In order to assess the problem of teaching mathematics effectively to 7<sup>th</sup> and 8<sup>th</sup> grade students, this study will first review literature regarding the use of reading and writing in teaching mathematics. TerraNova standardized test scores from Edgren High School will be discussed. Scores in mathematics will be compared by year and to other subject areas, including reading, language arts, science and social studies. The relationship of these scores to new

teaching methods employed at Edgren High School will be discussed. Finally, recommendations for further research will be made based on the findings of this study.

## Chapter II: Literature Review

This review provides a framework for the types of skills and proficiencies necessary for students to become fluent in reading and writing in mathematics and in the development of higher-level thinking. A review of the literature indicates that several components are most important to this study. These include the positive effect of teaching writing and reading mathematics on students' performance. The literature also provides information regarding the influence of educational psychology on educators' approaches and methods of teaching mathematics. This study is also informed by the principles and standards for school mathematics of the NCTM and their effect on standards of reading and writing in mathematics as a way of communicating the subject. A discussion of the application of teaching and assessment tools that educators can use in the classroom to enhance mathematics understanding is also provided.

### *Positive Effect of Teaching Writing and Reading in Mathematics*

In a study conducted by Bosse and Faulconer (2008), it was established that students learn mathematical concepts more deeply and effectively when reading and writing approaches are utilized. Although reading and writing in mathematics require more skills and mastery for both the teachers and the students, the positive effects outweigh the additional time and effort required (Bosse and Faulconer, 2008). Once this concept is accepted and incorporated into math curriculum, it will become easier for teachers and students to learn and teach through the use of reading and writing.

According to Zinsser, "we spend too much time in teaching arithmetic in the classroom when mathematics should be a discipline where people try to make sense of the world" (1998, p. 151). A fifth grade student is still learning the steps of how to solve problems by long division throughout the whole school year; a middle school student spends three years going over how to



add, subtract and multiply fractions. Including the reading and writing components of arithmetic and mathematics can help students to make connections between what they are doing and why they are doing it; and thus help them to move faster through the curriculum. Countryman (1992) stated that, “writing engages the imagination, the intellect and the emotions, and these are powerful ideas to learning” (p.10).

Similarly, Freitag (2000) in his paper “Reading and Writing in the Mathematics Classroom,” emphasized the positive effects of reading and writing in mathematics in relation to student’s performance in the subject. According to Freitag, reading mathematical texts can help students to write about math. Reading provides a guide and act as an example from which students can learn. During the reading process, students learn from the way symbols and notations are used, and words and concepts are situated within a context. In addition, Freitag notes, “Students can learn how logical progressions of ideas and concepts are developed and how the author justifies mathematical conclusions” (2000, p. 21). Therefore, students are given a guide for writing about math and mathematical concepts through reading.

Reading mathematics texts however requires a special set of skills; students must be able to read mathematically. According to Noonan (1990), reading mathematics texts effectively requires that students are able to “take the global meaning from the page, not just to be able to read a few sentences” (p. 79). The structure of the question must be understood, and the relationship of graphs and diagrams must be comprehended. To effectively read math texts students are required to possess a different set of skills and knowledge for successful comprehension. According to Noonan (1990), “The reading of a mathematics text is far more complex than simply being able to read the words on the page. It is about comprehending the mathematical ideas being put forward” (p. 79). Students must learn to comprehend mathematical

texts through practice and instruction. The more frequently the action of reading is performed, the more students' comprehension and writing abilities will improve.

Given the positive effects of this new approach to improving the performance of students in mathematics, one of the new goals for students as stated in the Curriculum and Evaluations Standards is,

The development of a student's power to use mathematics involves learning the signs, symbols and terms of mathematics. This is best accomplished in problem situations in which students have an opportunity to read, write, and discuss ideas in which the use of the language of mathematics becomes natural. As students communicate their ideas, they learn to clarify, refine, and consolidate their thinking. (NCTM, 1989, p. 6)

This clarification and refinement of thinking will aid in students' ability to learn mathematics, and to apply concepts and ideas in testing situations.

Outside the discipline of the language arts, the effectiveness of writing as a teaching tool has generated much interest (McIntosh, 1991). Grossman, Smith and Miller (1993) suggested that a student's ability to explain concepts in writing is directly related to the ability to understand and apply concepts in mathematics. Compared to other modes of learning such as listening, speaking and reading, Emig postulated that writing is "the most powerful and unique mode of learning" (1977, p. 21). This is due to the fact that writing encompasses all modes of learning: enactive, iconic and symbolic. Emig added that writing is effective because it originates from the student, and is also graphically recorded, stating, "the symbolic transformation of experience through the specific symbol system of verbal language is shaped into an icon by the enactive hand" (1977, p. 124).

Writing is powerful as it utilizes both the right and the left hemispheres of the brain. Emig explains that the right hemisphere of the brain facilitates “abstractions occurring as visual or spatial wholes” (1977, p. 125). On the other hand, the left hemisphere of the brain facilitates linear thinking connected to the process of structuring of ideas in a coherent way (Emig, 1977, p. 126). Aside from allowing both the right and the left brain hemispheres to work simultaneously and thus exercising the skill of linear thinking and structuring, writing is an effective tool because it allows for feedback. The process of writing allows the student to process information, and when information is made to be visually available the student is already reviewing the ideas for correctness. Finally, Emig stated that when students write, the slow pace of writing sets the condition for them to slow down thinking, allowing them to reason thoughts thoroughly (1977, p. 126). In addition, “writing clarifies and organizes a student’s thoughts” (Freitag, 2000, p. 18).

Shibli (1992) presents similar findings. In his study entitled “Increasing Learning with Writing in Quantitative and Computer Courses,” Shibli said that writing allows the student to develop the skills to analyze the steps in problem solving, and to draw conclusions and interpret from the solution (1992, p. 123). If a problem has more than one solution, writing helps to provide clarification and avoid ambiguity in interpretations (Shibli, 1992, p. 124).

### *The Influence of Educational Psychology*

Psychologists and educators have significantly influenced how mathematics is taught in the classroom. According to Morgan, psychologists and educators have highlighted the importance of teaching reading and writing in the content areas of mathematics as a tool for communicating the subject to the students, and to help students to become independent learners (1998, p. 45). Education is changing from a rigid discipline, where only the teacher has the knowledge and the answers to problems, towards a constructive discipline where students are

given the tools to learn independently. The Mathematical Sciences Education Board (MSEB) stated that, “To know mathematics is to investigate and express relationships among patterns” (1990, p. 12).

Until now, most of the mathematics taught in primary and secondary schools focus on arithmetic and algebraic algorithms in isolated concepts with no meaningful connections between them. Students memorize information for testing purposes and once the tests are over, they forget information quickly (Morgan, 1998, p. 46). Many students never come to see mathematics as a way to make connections, and sense of real life situations. Martinez wrote in her book *Reading and Writing to Learn Mathematics* (2001),

The discourse of mathematics classroom is changing... [From] teacher-talk, pencil and-paper calculations, and either-or thinking... Today teachers are encouraged to teach math through investigations, involving problem-solving skills where verbal and written communications are used. (p. 73)

Through these methods, students are able to interact with the information they are learning.

In his book, *Promise of Educational Psychology: Learning in the Content Areas*, Mayer discussed educational psychology in five major subject areas, including reading fluency and comprehension, writing, mathematics, and science (1999, p. 122). Mayer demonstrates “how psychological theories and research influence the development of better instructional practices and how real instructional problems influence the development of better psychological theories and research” (1999, p. 122).

#### *Education as a Process of Discovery*

The psychologist Bruner has contributed numerous concepts to research in education in areas of cognitive and learning psychology. In his constructivist theories, Bruner (1961) proposes

that education is basically a process of discovery. According to Bruner, knowledge builds upon knowledge, and new information has to be relevant in order to be remembered (1961, p. 13). It is important for students to connect previous information with new ideas to build understanding. Bruner also added that the theory of instruction should address three major issues, including the development of a predisposition towards learning, recognition of the importance of the structure information, and the importance of the sequence in which information is taught (1961, p. 20). Learning mathematics is about being able to figure things out without following a mechanical sequence or steps that is simply memorized. Bruner said that, "Mastering of the fundamental ideas of a field involves not only the grasping of general principles, but also the development of an attitude toward learning and inquiring, toward the possibility of solving problems on one's own" (1961, p. 20). The Committee on School Mathematics and the Arithmetic Project of the University of Illinois has also emphasized the importance of using investigation activities as an aid to teaching and learning mathematics.

According to Bruner (1961), when students learn they are active problem solvers and intuition plays an important role in the process. In addition, "The development of effectiveness in intuitive thinking is an objective of many of the most highly regarded teachers in mathematics" (Bruner, 1961, p. 56). Bruner distinguished between those students who can prove theorems or get the answer to difficult problems through mathematical rules and language, and those students can get the same answers who without having those skills. In high school, educators find that some students fear geometry, but can play sports and can calculate distances and angles perfectly. According to Bruner (1961), there are four important principles that can make learning easier: motivation; connecting formal facts with information students can relate to; structure and continuity; and exposing students to subjects without barriers (p. 56).

In their 2006 study titled “Self-Concept and Self-Efficacy in Mathematics: Relation with Mathematics Motivation and Achievement,” Skaalvik and Skaalvik performed two longitudinal studies that examined if mathematics self-perception affected students’ performance (p. 709). Skaalvik and Skaalvik focused specifically on “self-concept and self-efficacy,” to determine if these factors could predict “subsequent achievement over and above the prediction that could be made by prior achievement” (2006, p. 710). Regarding this study, Skaalvik and Skaalvik stated the following,

We...tested if the impact of self-perception on subsequent achievement could be explained by students' goal orientation, interest, or self-esteem. Participants were 246 middle school students and 484 high school students in study 1 and 2, respectively. (2006, p. 711).

Student achievement was assessed according to “final grades in two successive school years, whereas self-perceptions, interest and goal orientation were measured at the beginning of the second school year” (2006, p. 712). According to these scholars, the analyses of the data collected demonstrated that “students' self-perceptions strongly predicted subsequent achievement over and above the prediction that could be made from prior achievement” (Skaalvik and Skaalvik, 2006, p. 715). This demonstrates that the students’ attitude towards the subject of mathematics affects their performance and relative mastery of the subject.

### *Teaching Through Investigations*

Dewey was a philosopher and psychologist whose thoughts and ideas have influenced and modernized education all over the world. Some of his books were written for teachers and were used as an example for teaching. In 1910 Dewey wrote, “Every great advance in science has issued from a new audacity of the imagination” (p. 56). This quote summarizes the end to

which mathematical education is expected to lead. Dewey (1910) emphasized teaching through investigations, following the process of reflecting and evaluating ideas. Dewey (1910) asserted that intelligence is developed through experience and the interaction of individuals with their surroundings. Because of this, everything is subject to change, and is therefore not an absolute truth; what we know now is approximation and hypothesis, and can be altered through new discoveries.

Dewey (1910) asserted that learning is not a passive action; it builds upon experiences (p. 216). Life does not get better simply from acquiring more experiences; sometimes situations are unexpected, leading to experiences that have not been encountered before. New or challenging situations provide opportunities to think. Thinking means solving problems, providing an opportunity to learn. Several ideas presented by Dewey are central to this study, including the concept that processes of “conscious condensation” and summarization are imperative to learning (1910, p. 217). Like others discussed in this study, Dewey (1910) maintains the importance of motivation, asserting that “Educators should endeavor to keep students interested in what they teach, maintaining a balance between playful and serious activities” (p. 217). Dewey (1910) emphasized the relationship of learning and play, stating, “when comparative prominence in consciousness of activity or outcome is transformed into isolation of one from the other, play degenerates into fooling, and work into drudgery” (p. 217).

According to Dewey (1910), teaching is about nurturing and inspiring students. It is about making students want to know more. Students should be challenged to do new things. If old methods are not working, new methods should be incorporated into teaching. Dewey believed that when introducing new material to students, a connection between new information and previous knowledge should be established. Finally, Dewey believed in the power of

communicating other experiences to students, beyond what they are used to. Dewey added that, “Genuine communication involves contagion” (1910, p. 224).

### *Visible Thinking*

Gardner, psychologist and neuron-psychologist, is well known for the development of the theory of Multiple Intelligences and has been involved with the school reform movement in the United States. Gardner has conducted extensive research in education at Harvard University. The theory of Multiple Intelligences provided new insight on how students learn and how these ideas can be easily included in school curriculums. According to Gardner, there are many activities that can be used in the classroom to teach students to have a positive attitude towards thinking. Activities like starting class with meaningful idea documentation or any thinking routine, and following it with the appropriate questioning techniques, can help students to develop positive attitudes.

Visible thinking is one concept designed to enrich classroom learning in the content area of mathematics and to teach children to develop abilities, skills and a positive attitude towards thinking. Usually, thinking takes place inside of us and thinking is not visible, but teachers can help students through different classroom activities to visualize what is going on inside their minds. Gardner said that when thinking is visible, students “are in a position to be more meta-cognitive, to think about their thinking,” and that “students realize that school is not about memorizing content but exploring ideas” (1993, pp. 234-236). Concepts presented by Dewey reinforce these ideas. According to Dewey, “teachers can assess students because their thinking, misconceptions, prior knowledge, reasoning ability and degrees of understanding unfolds,” and teachers can help students to progress more effectively when “they know where they are” (1910, pp. 75-78).



Morgan is a lecturer in Mathematics Education. Morgan has written throughout her career in mathematic education. Her focus has been in mathematics education, linguistics and language issues in the study of mathematics teaching and learning, theory and practice of assessment of mathematics, especially assessment by teachers, social and political aspects of mathematics education, and last the education of mathematicians. Morgan (1998) was particularly concerned with how children think in mathematics and how teachers can help their students using writing assessments. Morgan, like Gardner, said, “writing provides the teacher with insight into students thinking” (1998, p. 45). According to Morgan (1998), the inclusion of writing in math classes can present challenges that arise from the expectations students and teachers have regarding the content of the course. Morgan states that the “pedagogic reason for using writing in math classes, and that is to improve students’ understanding (p. 24). Morgan presented guidelines to increase students’ understanding and problem-solving skills, recommending that students should be able to identify what is given and what is wanted in a problem. Student’s understanding can be increased when they try a small number of specific examples that illustrate the concepts presented. The action of copying the question in writing can also aid in comprehension (Morgan, 1998, p. 202).

Morgan (1998) added that writing in mathematics class stresses the role of organizing thoughts, and reflective and revised thinking. Teachers should pay attention to the language they use while teaching, so that students are introduced to a variety of ways to express the subject. According to Morgan, features of texts written by students that seem to be associated with judgments of high ability include the presence of algebraic expressions, abstractness, and the use of math terminology (1998, p. 244). On the other hand, some of the features associated with poor writing skill in mathematics include confusion in the use of terminology, and the use of language

and writing styles that are not appropriate in mathematics. Morgan asserts, “The use of writing in math classrooms can enhance the students understanding of the subject and help teachers to assess students” (1998, p. 224).

### *Standards for Mathematics*

The NCTM published the Curriculum and Evaluation Standards for School Mathematics, setting the direction for reform in the teaching and learning of mathematics (2008). The Standards present five general goals for all students: They should learn to value mathematics; become confident in their ability to do mathematics; become mathematical problem solvers; learn to communicate mathematically; and learn to reason mathematically (NCTM, 2008, p. 5).

According to NCTM, communication should be focused on mathematical tasks and should include activities that relate to important mathematical ideas. Additionally, students should recognize that there are multiple ways to find solutions and multiple representations. Effective communication in mathematics classes should give students ample opportunity to “interpret, justify and conjecture” (2008, p. 271). The NCTM also stated that written and oral assessments support students to think through problems and formulate explanations. Writing also allows students to practice new vocabulary and notations. Through written and oral communication, students learn to discuss mathematics and justify and criticized ideas (NCTM, 2008, p. 272).

Mathematics is not only about learning how to manipulate numbers; it is about interpreting what we are doing, how we are doing it, and why. According to the National Research Council (NRC), “strategic competence is the ability to formulate, represent, and solve mathematical problems” (2008, p. 5). This assertion relates to the ability of problem solving. The

NRC's concept of adaptive reasoning addresses "the capacity for logical thought, reflection, explanation, and justification," important in the ability to communicate ideas (2008, p. 7).

### *Other Influences*

Zinsser, a writer, editor and a teacher, has contributed extensively to education and has written many books, including *Writing to Learn: On Writing Well*. Zinsser is famous for such quotes on writing as "writing is thinking on paper" and "writing and learning and thinking are the same process" (1998, p. 245). According to Zinsser, "most of us see mathematics as a world of numbers with always a right answer" (1998, p. 88). In addition, Countryman stated, "it is fine to get the right answer, but what good is that answer if you can not explain it to anyone" (1992, p. 153). Teaching students to think and organize their thoughts is a challenge that teachers have to face no matter what subject they teach. Teaching how to write is teaching how to think, how to put thoughts in order, and to think logically. According to Zinsser, "Writing is a tool that enables people in every discipline to wrestle with facts and ideas" (1998, p. 49).

Math teachers are going to face barriers when attempting to change their methods of teaching mathematics, especially in a discipline so closely related to numbers. Zinsser stated that, "Resistance to new teaching methods usually takes one of two forms: conservatism or inertia" (1998, p. 167). Resistance occurs because of inertia, and teachers do not want to change their old ways because it takes too much time to teach more than an algorithm. The best way to assess and evaluate what students understand about the concepts math teachers are introducing is by asking them to explain and interpret the concepts being taught.

Borasi is a mathematics educator working with elementary and secondary school teachers as well as doctoral degree students. She is involved in school reform, creating professionalism for teachers, and has special interest in the inquiry approach to teaching. In her 1996 book,

*Preconceiving Mathematics Instruction: A Focus on Errors*, Borasi said that teachers should decrease attention in computation errors and focus on mathematical thinking and problem solving through the approach of “writing to learn mathematics” (p. 33). Borasi, like other researchers, believed that students should not simply memorize how to solve a problem, but should approach problems in different ways without perusing a single solution (1996, p. 33). This has been called the “successive draft approach” (Borasi, 1996, p. 33).

Countryman is the head of Lincoln School in Providence, Rhode Island. Countryman is a mathematics teacher and a lecturer who has done extensive research in mathematics education. Countryman (1992) encouraged educators to teach students the connection between writing, thinking and learning mathematics. In her book *Writing to Learn Mathematics* Countryman said, “Many teachers and students resist the idea that writing belongs in mathematics classrooms” (1992, p. 153). Countryman further stated that many mathematics teachers and students claim to pursue a mathematics career because they believe that writing is not associated with mathematics. Burns said, “One reason I majored in mathematics in college was that papers were not required” (cited in Countryman, 1992, p. 1). Countryman stressed the idea that the use of writing exercises in math classes can help students to understand the subject and develop better communication skills (1992, p. 1).

According to Countryman, learning mathematics is about interpreting unfamiliar texts, constructing ideas, understanding complex systems, posing questions and evaluating alternative responses to those questions (1992, p. 85). Students have to be trained to organize, interpret and communicate ideas. Through writing and communication students learn to see math not only as a collection of number, formulas and logarithms, but as a process that students can contribute to through dialogue. Countryman posits the question, “why waste time teaching [students] to solve

quadratic equations when calculators do that for us and teaching students how to solve real life situations where quadratic equations are required is more effective?” (1992, p. 85). Some of the techniques she has used in her classroom include journals entries, student’s autobiographies, logs, and diaries. This is in agreement with the ideas of the NCTM who stated that, “writing in the mathematics classroom can take many forms” (2008, p. 8).

### *Teaching and Assessment Tools*

Various research on these topics have produced a number of teaching and assessment tools that may be employed by both teachers and students in writing and reading mathematics. In a study conducted by Sipka (1990), writing in the mathematics classroom was classified into two categories, informal and formal. Informal writing involves content as the main criterion for the judgment of the paper. Informal writing is useful in helping students in comprehension, and includes mathematics autobiographies, reading logs, journals and free writing (Spika, 1990).

According to Drake and Amspaugh (1994), student writing can provide many benefits to teachers as well as students. The review of written explanations of the processes students use to solve problems can allow teachers to understand and assess student’s thinking and comprehension of material in a way that computational steps alone may not provide. Thus, teachers can diagnose and address errors in a student’s thinking or knowledge of procedure more effectively (Drake & Amspaugh, 1994, p. 45). The depth of a student’s misunderstanding can be determined by the teacher, and thus provide insight for an instructional starting point. A teacher may not always need to start from the beginning of a process in order to clear up a misconception. According to Drake and Amspaugh, having a student write may provide the instructor with “evidence of where or why a student has failed to make connections between

strands of the mathematics curriculum” (1994, p. 45). The assessment of writing may also lead to the discovery of the root causes as to why students are not able to solve problems independently.

### *Spontaneous reflection writing*

Spontaneous reflection writing can be used to find out if students are ready to start a new topic, test previous knowledge, have misconceptions of the topic to be covered, or have simple fears for the subject. NCTM recommends using this type of assessments “as a quick start at the beginning of the class” (2008, p. 30).

### *Journals*

Journals are writing assignments and involve writing about topics that have been covered in class. According to Countryman, “a journal is a chart of the students’ journey through the course and a way to keep track of where they are going, and where they have been, as they struggle with the stuff of mathematics” (1992, p. 27). Learning how to formulate ideas and express them in writing is extremely important to complete any mathematical curriculum. Burns said that, “Writing helps students sort out, clarify, and define their thinking” (2004, p. 127). Writing also can help teachers to better understand students’ thinking.

Journals create records of what students learn and turn students into mathematics journalists. Journalists chase down stories, search for an answer. Journalists have an inquisitive attitude and ask questions. They are actively searching for answers and to find different approaches to present information to their target audience. Journals are more effective if begun at the beginning of the school year. Teachers communicate their expectations at the time when students are going to have to write, and will also explain how many times a week or the type of questioning they should to write about. According to Countryman, “No single method of journal keeping works for every teacher” (1992, p. 38). The same teacher can change and adapt methods

according to the class' needs, but no teacher should criticize what a student writes or how he or she writes in a journal entry. Burns recommends giving students three guidelines to help them in their writing, including asking them to write about what was done in class, what they learned, and to write about anything they are not sure or wondering (2004, p. 51).

According to Martinez and Martinez (2001) some of the beneficial characteristics of student's logs or journals include allowing students to "think aloud on paper", and giving them the feeling of "owning the answer" (p. 10). By mixing the use of ordinary language and mathematics language, students are able to relate to the information, and are presented with the opportunity to explain mathematical concepts in their own words. Students are also given the opportunity to explain specific difficulties they are having, which allows them to express themselves and gives teachers valuable insight to help them overcome difficulties (Martinez & Martinez, 2001, p. 10)

According to Waywood (1992), journals can either be a summary of information, reinstatement of information or a mode of dialogue with the teacher. Teachers are expected to encourage the students to ask probing questions and then provide explanations of the topics being taught in class, in addition to this being a venue for communication between the teachers and the students with regards to concerns, difficulties and misunderstandings.

#### *Summaries and explanations*

Written assignments where students summarize what they read or what they know and understand can help students to not only to remember but also to extend ideas and make connections. According to Martinez and Martinez, "Explaining concepts can help to remember and extend ideas" (2001, p. 11). Also, teachers can assess students, correct misunderstandings, clarify ideas, and see how students think. Burns added, "In assignments like this I find students

give me the information that I find intriguing, sometimes surprising, and usually helpful for assessing their understanding” (2004, p. 83).

### *Free write or creative writing*

Sipka (1990) said that one of the non-standard informal writing assignments is the free write, which is basically a “stream of consciousness” style of writing. This is not as structured as the other assignments but in fact, allows students to jot down every idea that comes into their minds. This kind of assignment allows for the capture of random thoughts and develops the skill for idea generation. Sipka recommended putting a restriction of five minutes or less to control the length.

These types of assignments are also useful to help those students that feel more confident about writing than doing mathematics, thus giving them opportunities to express how they feel about certain mathematical concepts. According to Countryman, free writing in math helps students to wonder, speculate and experiment with new ideas, allowing students to record what they know and what they do not know (1992, p. 88).

Some of the greatest mathematicians have also been creative writers, such as Abbott who wrote the book *Romance of the Fatland Square*, and Lewis Carroll who wrote *Alice in Wonderland* and *Through the Looking Glass*. A new trend in education encourages teachers to use writing across the curriculum. Burns gave three basic reasons for this; “to give the students a fresh way to think about mathematics; to bring students writing straight to math assignments; and to broaden student’s view of mathematics” (2004, p. 103). However, Burns (2004) notes importantly that writing in mathematics is not creative and is used mainly to reflect on student learning and communicate ideas about mathematics.



### *Mathematics autobiography*

Sipka (1990) added that in mathematics autobiography the students write down their experiences in mathematics as a subject and in the classroom. One particular example that Sipka noted is to ask the students to write about their experience regarding learning a particular mathematical concept. Through this, the teacher is able to know the attitudes and beliefs of each of the students, thus allowing him or her to apply the necessary approach to assist the learning process for each student.

### *Word problems*

In solving word problems, two steps have been recommended by Cut-the-knot.org, a website devoted to the promotion of children's math success. These steps are to first "translate the wording into a numeric equation that combines smaller 'expressions,'" and then solve the equation (Cut-the-knot.org, n.d., ¶6). This two-step approach to solving word problems in mathematics gives the student their first real world example on how mathematics relates to everyday experience. We use word problems to study simple equations. According to Cut-the-knot.org, word problems must be "translated into the language of mathematics, where we use symbols for numbers, known or unknown, and for mathematical operations" (n.d., ¶6). Once the problem is solved, the answer "can be translated back into the ordinary language" (n.d., ¶6).

### *Reshaping School Mathematics*

The Mathematical Sciences Education Board (1990) stated in their publication titled, *Reshaping School Mathematics: A Philosophy and Framework for Curriculum* that, "Mathematical language is clear and succinct" (p. 9). It is important to recognize that mathematical formulations should be limited to information that is important to the problem. Students should learn to determine what is important and what is not. According to the MSEB,

“One simple approach to find out is to try changing the problem a small piece at a time,” and to take note of “small modifications that do not distort the meaning of the problem” (1990, p. 9).

### Chapter III: Methodology

This chapter will describe and evaluate the subject of study and the procedures that were followed to complete it. In order to support the findings from the Review of Literature and for the purpose of triangulation, this chapter will discuss data gathered from the TerraNova standardized tests for 7<sup>th</sup> through 11<sup>th</sup> grades during the years 2002 through 2007, with a particular focus on 7<sup>th</sup> and 8<sup>th</sup> grade students in the years 2006 and 2007. Limitations encountered during this study will also be discussed in this section. The TerraNova is a standardized assessment test on areas including mathematics, science, social studies, reading and language arts for K-12 students. Similar questions, directions, time limits and scoring criteria are administered wherein scores are compared with students from other states on the same grade level.

The purpose of this study is to help the Edgren High School staff and the mathematics department to set up new goals to improve writing and reading in the core curriculum, particularly for the 8<sup>th</sup> grade math teacher, based on the TerraNova scores. Math educators in 8<sup>th</sup> grade, for one year will implement new methods of teaching the subject including reading and writing activities and assignments to help students comprehend math.

#### *Subject Selection and Description*

Students enrolled in 2005-2006 7<sup>th</sup> grade math and 2006-2007 8<sup>th</sup> grade math at Edgren High School were exposed to methods of teaching mathematics wherein reading and writing assignments were utilized daily in the classroom to increase their level or understanding of the subject. During this time the instructor not only taught students algorithms, but also taught them how to read and write in the content area using appropriate terminology and language.

Those students that were able to stay at Edgren High School for two consecutive years were able to participate in this study.

Every five years, Edgren High School establishes goals to improve student scores in its core curriculum. Students are tested every year using the TerraNova Standardized test to measure their achievements in the basic skills of reading, writing, social studies, science and mathematics. In 2007, teachers and administrators developed a plan that will be implemented for the next five school years in every subject. The goal is to enhance critical thinking across the entire curriculum and improve student writing skills and comprehension.

This study will focus on the math scores from TerraNova tests administered to 7<sup>th</sup> and 8<sup>th</sup> graders in 2006 and 2007, as well as analyze scores in mathematics and their relationship to other academic subjects over a six-year period between 2002 and 2007. While the main concern of this study is the performance of 7<sup>th</sup> and 8<sup>th</sup> graders in mathematics in 2006 and 2007, the analysis of data from a longer period of time will allow for the situation of these results within a larger context. In addition, the assessment of scores of students in higher grade levels will also allow for potentially interesting ideas arising from the comparison of data and averages. It is appropriate to discuss the scores of students in 9<sup>th</sup> through 11<sup>th</sup> grade as these students were also exposed to reading and writing in mathematics. This will also allow for the assessment of the scores of a particular class of students as they progress from 7<sup>th</sup> grade through to 11<sup>th</sup> grade over a five-year period from 2003 through 2007.

According to the Department of Defense Education Activity (DoDEA), the TerraNova is a standardized test that is norm-referenced. According to information available on the DoDEA Data Center website,

[This] achievement test... compares students' scores to scores from a 'norm group.' The norm group for TerraNova is a national sample of students representing all gender, racial, economic, and geographic groups. (n.d.)

The TerraNova provides information that is consistent, accurate, and objective regarding the achievement of students in a variety of areas of the curriculum.

According to Inderbir Kaur Sandhu, the standardized, norm-referenced nature of the test allows for the comparison and assessment of the scores (2008). According to Sandhu,

Individual or group scores may be compared... with the scores of other students in the class, school, district, or national norm group. Test results can also be compared over time intervals, which is one indication of growth for an individual or group of students. (2008)

This study will utilize this method of comparison to determine if the effects of reading and writing in mathematics class are reflected in TerraNova scores from Edgren High School.

Because a single scale is used for each content area, scores can be compared over time.

However, each content area is scaled differently so they cannot be compared with scores in another content area (Sandhu, 2008). In order for achievement in different content areas to be compared scores are converted and reported as percentiles based on "a NCE, Normal Curve Equivalent (range from 1 – 99)" (Sandhu, 2008).

It is important to note that TerraNova scores are reported in percentiles rather than percentages. According to the DoDEA,

A percentile is a measure of comparison that ranks one score against the scores of all

other test takers. For example, a 75 percentile score means that 75 percent of all other test takers nationally scored below and 25 percent scored above that score. The national average is always the 50<sup>th</sup>ile. (n.d.)

Therefore, TerraNova scores discussed in this study represent the performance of Edgren High School students in relation to national averages.

### *Instrumentation*

To support the result of this new implementation, teachers at Edgren High School will follow the scores of the TerraNova Standardized test of the 7<sup>th</sup>- 8<sup>th</sup> grade students during the school year 2005-2006 and 2006-2007 to validate this new project. In order to assess the shifts in student achievement in mathematics TerraNova scores have been averaged in this study and compared in a variety of ways. First, scores in 2006 and 2007 will be discussed, as this is the main focus of this study, particularly in relation to grades 7 and 8. Averages over six years will then be compared to determine the relative achievement in mathematics in contrast to other content areas, including reading, language arts, science, and social studies. This will include a discussion of all grades of students tested at Edgren high School, 7<sup>th</sup> through 11<sup>th</sup>. Then the achievement of 7<sup>th</sup> and 8<sup>th</sup> grade classes from 2002 through 2007 will be discussed. Lastly, the scores of a specific group of students will be discussed as they move from 7<sup>th</sup> grade in 2003 to 11<sup>th</sup> grade in 2007. The performance of these students will be analyzed in relationship to their performance in other content areas. This comparison is made possible by the fact that TerraNova scores are given in percentiles based on a norm average.

### *Data Collection Procedures*

All data regarding TerraNova test scores at Edgren High School is public information retrieved from the Department of Defense Education Activity Data Center website. Upon

review, this study has been exempted from oversight by the University of Wisconsin-Stout's Institutional Review Board (IRB).

### *Data Analysis*

The test scores of both Grades 7 and 8 on reading and math will be compared and analyzed to determine how the scores in reading will compare to math scores over a two-year period. In addition, the math scores of Grades 7 and 8 in 2006 will be compared the results in 2007 in order to determine whether the teacher's utilization of the reading and writing in mathematics approach led to an increase in the students' performance in math. In addition, TerraNova scores have been averaged and compared in a variety of ways to reveal trends and shifts in mathematics achievement over the past six years.

### *Limitations*

This study is limited by the fact that information regarding the specific reading and writing activities implemented in mathematic classes is not currently available. In addition, a controlled study has not been conducted at this point in time. This makes it impossible to reach conclusions regarding the causes of shifts in test scores, as factors that may affect change have not been isolated. These factors may include class size, consistency of student population, and the lack of specific information regarding the teaching methods employed in mathematics classes. Also, while the TerraNova test is standardized, teaching methods and styles are likely to vary from teacher to teacher. While data regarding TerraNova scores is available as early as 1998, a new edition of the test was released by McGraw Hill in 2002 (DoDEA Data Center, n.d.). Because the 2<sup>nd</sup> edition TerraNova test was normed to a more inclusive sample of the student population, scores prior to 2002 cannot be significantly compared to those collected between 2002 and 2007 (DoDEA Data Center, n.d.).

It is important to note that the positive effects of reading and writing in mathematics class may not become distinctly apparent at the beginning of their implementation. It may take time for teachers and students to become accustomed to teaching and learning in a new way. In addition, it has been established in the literature review section of this paper that new knowledge tends to build upon previous knowledge, thus it may take time for concepts learned through reading and writing to be absorbed if students are not used to learning in that way.



## Chapter IV: Results

In this section, TerraNova test results from Edgren High School will be analyzed and discussed in relationship to the literature regarding reading and writing in mathematics classes. Through a particular emphasis on test scores of 7<sup>th</sup> and 8<sup>th</sup> grade students in 2006 and 2007, trends regarding mathematics scores will be discussed in relationship to other subject areas, including reading, language arts, science and social studies. TerraNova scores collected between 2002 and 2007 will also be discussed to provide additional information.

Table 2

*Results of the TerraNova Standardized Tests for 7<sup>th</sup> and 8<sup>th</sup> grade Students at Edgren High School, 2007.*

Year	Grade	Number of students	Reading	Language Arts	Math	Science	Social Studies
2007	7	101	65%ile	71%ile	72%ile	66%ile	62%ile
2007	8	95	68%ile	68%ile	71%ile	68%ile	69%ile

Table 3

*Results of the TerraNova Standardized Tests for 7<sup>th</sup> and 8<sup>th</sup> grade Students at Edgren High School, 2006.*

Year	Grade	Number of Students	Reading	Language Arts	Math	Science	Social Studies
2006	7	97	66%ile	71%ile	73%ile	58%ile	62%ile
2006	8	100	72%ile	68%ile	71%ile	70%ile	65%ile

As is depicted in Table 2 and Table 3, the TerraNova mathematics scores of 7<sup>th</sup> and 8<sup>th</sup> grade students at Edgren High School for two consecutive school years demonstrate that scores

have not shifted significantly from 2006 to 2007. While the school's program on reading and writing in mathematics has been implemented, the performance of students in mathematics in Grade 7 decreased from the 73 percentile in 2006, to 72 percentile in 2007. Reading scores also showed the same trend, with a decrease from the 66 percentile in 2007, to the 65 percentile in 2007.

For Grade 8, the achievement score in mathematics did not change, maintaining 71 percentile, while the reading scores decreased more significantly from the 72 percentile in 2006 to the 68 percentile in 2007.

Table 4

*Average TerraNova scores for all students at Edgren High School grades 7<sup>th</sup> through 11<sup>th</sup> grades, 2002 to 2007.*

Year	Average Overall Percentile	Average Math Percentile	Rank
2007	72%ile	74%ile	1 <sup>st</sup>
2006	72%ile	75%ile	1 <sup>st</sup>
2005	71%ile	72%ile	2 <sup>nd</sup>
2004	72%ile	71%ile	5 <sup>th</sup>
2003	71%ile	71%ile	3 <sup>rd</sup>
2002	71%ile	70%ile	4 <sup>th</sup>

Table 4 depicts the average scores of all students who participated in the Terra Nova standardized test at Edgren high school from 2002 to 2007. Students' scores have been averaged for all grades and all five subjects tested, including reading, language arts, math,

science and social studies. The averages of math scores for 7<sup>th</sup> through 11<sup>th</sup> grades have also been calculated by year. The fourth column in the table shows the position of the math scores in relation to the other four subjects.

Students' scores in all subjects varied only slightly from the 71 percentile in 2002, to the 72 percentile in 2007. Math scores ranged from the 70 percentile in 1998 to the 75 percentile in 2006 and the 74 percentile in 2007. The relative position of mathematics in comparison to reading, language arts, science, and social studies increased from 4<sup>th</sup> place in 2002 and 5<sup>th</sup> in 2004, to 1<sup>st</sup> in 2007. The rank of math scores jumped from 5<sup>th</sup> place in 2004 to 2<sup>nd</sup> in 2005, and maintained 1<sup>st</sup> place in 2006 and 2007.

Table 5

*Average TerraNova scores of 7<sup>th</sup> grade students at Edgren High School, 2002 to 2007.*

Year	Average Overall Percentile	Average Math Percentile	Rank
2007	67%ile	72%ile	1 <sup>st</sup>
2006	66%ile	73%ile	1 <sup>st</sup>
2005	65%ile	72%ile	1 <sup>st</sup>
2004	63%ile	65%ile	2 <sup>nd</sup>
2003	66%ile	66%ile	3 <sup>rd</sup>
2002	68%ile	68%ile	3 <sup>rd</sup>

Table 6 includes the average scores of 7<sup>th</sup> grade students at Edgren High School between 2002 and 2007. It is interesting to note that the average scores of 7<sup>th</sup> grade students

tested in all subjects at Edgren high school between 2002 and 2007 remained fairly stable, ranging between the 68 percentile in 2002 and the 67 percentile in 2007. When math scores are isolated however, the shift becomes larger, demonstrating an increase ranging from the 68 percentile in 2002, and the 72 percentile in 2007. The largest shift in math scores is evident through the comparison of the 65 percentile in 2004, and the 74 percentile in 2006. In addition, it is interesting to note that scores in mathematics were lower than scores in other subjects with math ranking 3<sup>rd</sup> in 2002 and 2003. In the years 2005, 2006, and 2007 however, math was the highest ranked subject of the five.

Table 6

*Average TerraNova scores of 8<sup>th</sup> grade students at Edgren High School, 2002 to 2007.*

Year	Average Overall Percentile	Average Math Percentile	Rank
2007	69%ile	71%ile	1 <sup>st</sup>
2006	69%ile	71%ile	2 <sup>nd</sup>
2005	68%ile	69%ile	2 <sup>nd</sup>
2004	70%ile	72%ile	1 <sup>st</sup>
2003	72%ile	75%ile	1 <sup>st</sup>
2002	73%ile	78%ile	1 <sup>st</sup>

As revealed in table 7, the average scores of 8<sup>th</sup> grade students at Edgren High School in all subjects decreased from the 73 percentile in 2002 to the 69 percentile in 2007. Scores in mathematics also declined, from the 78 percentile in 2002 to the 71 percentile in 2007. It is

interesting to note, however, that math scores increased over the past three years from the 69 percentile in 2005 to the 71 percentile in 2006 and 2007. 8<sup>th</sup> grade math scores maintained a ranking of first or second place in comparison to other subject areas between 2002 and 2007.

Table 7

*Average TerraNova scores for students in 7<sup>th</sup> grade in 2003 through 11<sup>th</sup> grade in 2007.*

Number of Students	Grade	Year	Average percentile All Subjects	Average percentile Math	Rank
73	11 <sup>th</sup>	2007	77%ile	83%ile	1 <sup>st</sup>
85	10 <sup>th</sup>	2006	77%ile	81%ile	2 <sup>nd</sup>
106	9 <sup>th</sup>	2005	72%ile	75%ile	1 <sup>st</sup>
127	8 <sup>th</sup>	2004	70%ile	72%ile	1 <sup>st</sup>
144	7 <sup>th</sup>	2003	66%ile	66%ile	3 <sup>rd</sup>

When the achievement of one class of students is analyzed from their entrance into 7<sup>th</sup> grade in 2003 through the 11<sup>th</sup> grade in 2007, significant shifts are revealed. As is shown in Table 8, overall performance in all subjects tested by the TerraNova increased from the 66 percentile for 7<sup>th</sup> graders in 2003 to the 77 percentile for 11<sup>th</sup> grade students in 2007. The scores of this class also improved significantly in the subject area of mathematics, jumping from the 66 percentile for 7<sup>th</sup> graders in 2003 to the 83 percentile for 11<sup>th</sup> grade students in 2007. It is important to note that the causes of these shifts are currently impossible to determine fully, since the stability of the student population has not been established. In addition, other factors, including class size, may affect the performance of students during TerraNova examinations.

While TerraNova scores from Edgren High School demonstrate some interesting shifts, further study is needed to determine their cause and relationship to reading and writing in mathematics. While it has been established that there is wide support for such methods in education research and theory, further study and information is required to determine the effect of these methods on standardized test scores.

Numerous materials discussed in the literature review reveal the growing interest in using reading and writing approaches in teaching mathematics. Educational psychologists like Bruner and Dewey have attempted to improve teaching and learning through the incorporation of interactive activities in the classroom. The theories derived from their observations have, in no small way, contributed to our understanding of the education process.

Researchers and educational psychologists such as McIntosh, Emig, Shibli, Mayer, Bruner, Skaavik and Skaavik, Dewey and Gardner have expanded our understanding of the learning process. According to these scholars, new knowledge is built on prior knowledge, and the learning process is basically about making sense of an individual's surroundings, as stated in Bruner's constructivist theory. In addition, researchers and educational psychologists have postulated that other factors influence the performance of students in mathematics, including self-concept, and the attitude of students towards learning, inquiring and solving problems. Motivation is also another factor that influences achievement scores in mathematics. According to the literature, positive motivation translates to better performance in mathematics. In their contributions to educational thought and practice, these researchers have stressed the important role that reading and writing play in the classroom. These theorists have encouraged the use of a variety of exploratory methods and technology to improve learning and stressed the positive effects of giving students writing assignments in mathematics.

These findings support the idea that reading and writing in mathematics have a positive impact on the performance of students. While many students never come to see mathematics as a way to make sense and connections to real life situations, modern day educators say categorically that the discourse regarding mathematics classrooms is changing as teachers in mathematics today are encouraged to teach math through investigation, involving problem solving skills where verbal and written communications are used. Research conducted by Zinssner, Morgan, Bosse and Faulconer, Countryman, Freitag, Noonan, Martinez and the NCTM have established that writing is a powerful tool for learning as the process is enactive, iconic, and symbolic. Furthermore, it has been established that the ability to explain concepts in writing is directly related to the ability to understand and apply concepts.

Although the earlier trend was to treat mathematics as purely related to numbers, research on the effects of new approaches and methods in teaching the subject are now changing teaching in math classrooms. In applying the approach of incorporating reading and writing in mathematics in teaching the subject, the idea of utilizing the student's prior knowledge and making the learning process experiential is supported and reinforced. Teachers have shifted from teaching students to memorize mathematics to teaching students mathematics through investigations where problem-solving skills are used. The NCTM at the end of the 20<sup>th</sup> century set the direction for reform in teaching and learning mathematics. According to the NCTM, teachers should include in their daily assignments important mathematical ideas, give students the opportunity to find answers using multiple representation and opportunities to communicate what they learn orally or through writing.

As mathematics is all about investigating and expressing relationships among patterns, the literature demonstrates that reading and writing in mathematics develop the necessary skills

to increase the students' comprehension and application of mathematical concepts. Thus, modern educators are imbibing aspects of the recommendations contained in the theories. The right hemisphere of the brain, which is the part that facilitates the abstraction of concepts, and the left hemisphere of the brain, which facilitates linear thinking, are both at work during the activity of writing. Writing then trains both the left and the right hemispheres of the brain to work simultaneously, facilitating the processing of information more quickly and accurately to arrive at the right solutions in solving equations and absorbing mathematical concepts.

The process of writing forces the student to slow down, and thus allows for the thorough processing of information, and also the review of the mathematical concepts studied. Writing in mathematics develops the skills of analyzing the steps in problem solving, drawing conclusions and interpreting from the solution. Writing mathematics develops the skills of organizing one's thoughts and develops reflective and revised thinking. Researchers came up with writing assignments that can be utilized in teaching mathematics and assessing the development and capacity of students, which have been classified as either formal or informal writing. Such types include spontaneous reflective writing, journals, summaries and explanations, free write or creative writing, mathematical autobiography and word problems.

Research has also shown that reading promotes among the students the development of the skill to use certain symbols and notations, and helps them to learn how the author contextualizes each word. The students, in reading mathematics texts, also develop their skills of understanding the logical progression of ideas and concepts. In reading mathematics, students learn to refine, clarify and communicate their thinking.

Thus, the mastery of language not only helps the student to understand the processes of solving mathematical and allied problems, but it also empowers the student to master other



academic disciplines which require clarity of thought in the understanding of course content. In order for students to gain the desired mastery of mathematics through reading and writing, teachers need to explore new methods in teaching, reading, and writing mathematics through the practice of constructivism learning which includes methods of investigation, reasoning, and communication. The NCTM has helped to push teachers in this direction by establishing standards for the teaching of reading and writing as component parts of the mathematics curriculum. According to the NCTM standards of mathematics, students have to be proficient in communicating mathematics. In order for students to achieve this laudable objective, their mathematics teachers must become proficient and efficient in communicating the subject to them.

## Chapter V: Discussion

This study is related fundamentally to the fact that the performance of primary students in the United States in mathematics is consistently getting poorer, as is shown by international and national tests. The results of this study reinforce the concept that mathematics is still popularly conceived as a subject that deals solely with numbers. The concept that the learning process builds on experience and that new knowledge is built on existing knowledge is foundational to the promotion of reading and writing in mathematics classes. Teaching methods in the mathematics classroom are slowly changing as mathematics teachers using new pedagogic approaches and tools. Reading and writing in mathematics have a positive influence on the performance of students in mathematics by developing the necessary skills. These findings have major implications on mathematics curriculum development and the teaching strategies and roles of mathematics teachers in the primary and secondary levels.

For one, given that other factors influence the achievement scores, teachers have the responsibility to create an environment and relationship with his or her students that will be more conducive to learning mathematics. In particular, teachers must be able to motivate students in learning the language and must be able to assist in creating or fostering a healthy attitude among the students towards self-concept, learning and inquiring. This has an implication on the teaching tools and strategies of the mathematics educator. In order for students to achieve objectives, their mathematics teachers must become proficient and efficient in communicating the subject to them. In addition, the findings have implications on the education curriculum. Steps have been made by the NCTM through the incorporation of the need for students to be proficient in communicating the subject into mathematics standards. The mathematics curriculum must be able to incorporate writing and reading subjects related to math.

As the student's thinking is invisible and yet important for the teachers to understand, reading and writing tools can be effective in visualizing thinking. This can be achieved by employing tools such as mathematical autobiographies, journals, summaries, and creative writing. Through the use of these tools, the teacher will be able to assess the students' thinking, misconceptions, and abilities. Educators must be able to teach through investigations, and the process of evaluating ideas.

As writing and reading in mathematics require a different set of skills from that of reading and writing literature, the teacher must be knowledgeable and updated on the theories of learning, and the existing and upcoming pedagogic tools on writing and reading in mathematics. Teachers of mathematics can help themselves, and by extension their students, to attain the objectives of the NCTM through life-long education. Peer group tutoring of entry-level teachers, attendance at workshops and seminars as well as self- help through reading will help practicing teachers to uplift their students' performance in language arts as a vehicle to better understanding of mathematical processes. Hence the best approach to the present poor performance of students in mathematics is to encourage teachers to improve their language communication skills, and then to use the knowledge so acquired, to impart their skills to their students. The best way forward in our bid to improve performance of students in mathematics examinations is to improve their reading and writing skills in relation to mathematics.

There have been great changes in life of the school system, both inside and outside the classroom. In past years, schools in the United States taught mathematics to students through mastery of the mechanical manipulation of mathematical symbols. Recent researches in both education and psychology have exposed this mechanical process of imparting mathematical knowledge as defective. Today, educators have come to realize that students need to improve

their language reading and writing skills in order for them to be proficient in mathematics and allied subjects. Owing to the concerted efforts of dedicated educational researchers, educational psychologists, theorist, and professional educators, a lot is being achieved in promoting student understanding of the mathematical processes through better proficiency in reading and writing. We are moving towards innovative practices of teaching and preparing students to confront a more sophisticated society where problem solving skills and higher-level thinking are not only required, but also necessary to the attainment of a better understanding of modern life.

Psychologists in education, such as Bruner (1961) and Dewey (1910) have supplied education with numerous concepts. Many other professionals have influenced how teaching can be modified to enhance learning. The history of cognitive and learning psychology has contributed in the development of children's learning during the past decades. These important studies have helped in the evolution of education and therefore the development of children from childhood to adulthood.

The issue of teaching writing and reading as part and parcel of mathematics in the classroom continues to surface as one of the most challenging problems in education. It is now on the forefront of educational thought and practice. Educators and educational psychologists have, over time, come to realize the importance of students' ability to communicate their thoughts in writing, just as they normally do in other non-mathematical subjects. We have gone from limiting the teaching of mathematics to arithmetic and algebraic algorithms, to now include the teaching of mathematics through such activities as investigation, using problem solving skills and higher level thinking. While the environment in mathematics classrooms is changing, incorporating fresh and positive attitudes towards new pedagogic approaches and strategies, the

students, parents, and the whole academe must keep an open mind to the idea of reading and writing in mathematics as an effective pedagogic tool.

### *Limitations*

One limitation of the study is the limited period, number of subjects and data on the TerraNova scores of Grades 7 and 8 students at the Edgren High School. The data analyzed did not show any significant results and was not a strong support to the hypothesis. Insufficient information regarding teaching methods and the performance of students also hindered the significant analysis of data collected from TerraNova examinations.

Another limitation is that all of the materials used in this study were drawn from American research, and the subjects and setting was in the United States. There may be an issue on the possibility of replication, especially in nations where the culture is entirely different as concepts such as self-concept and motivation are discussed. In addition, information regarding the teaching methods employed in other countries may generate new ideas and add to the discussion significantly. Additionally, the results and conclusions of this study can only be applied by educators and teachers who are open to the idea, given the current situation wherein majority of parents, students and the academicians relate mathematics to numbers only. While the analysis of data provided in this study discussed the shifts in TerraNova scores in mathematics at Edgren High School, no significant conclusions can be made regarding the relationship of these scores to teaching methods without additional information.

### *Recommendations*

To validate the data of this research, future studies should conduct a long-term and comprehensive study, and more importantly, quantify the effect of reading and writing in mathematics on the achievement scores of students on the subject, across states and across grade

levels. In connection to this, tools must be developed to accurately measure the progress of the student in mathematics and to assess the progress in skills in reading and writing in mathematics. Furthermore, it is also recommended that similar materials or studies from different countries be studied and also conducted to resolve the issue of the universality of the idea and replication of the result findings. It is also recommended that all pedagogic tools on reading and writing in mathematics be exhausted and for new ones to be developed if possible. Each tool in writing and reading in mathematics can be measured to determine the strength and weaknesses of each and determine as to what situations they are applicable.

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