WRITING IN MATHEMATICS

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WRITING IN MATHEMATICS

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by

Livia Doyle

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I share, admittedly, that at the beginning, I had not the slightest idea as to what I would gain from this journey. Rather, receiving my master's degree in education was once just a progression in my educational career I so incredibly yearned to achieve. Undoubtedly, to much of my surprise, this journey proved to be so much more. The time I have spent learning and growing professionally was not at all anticipated, yet gratefully received. My pedagogical practices have been forever changed as I approach all aspects of my teaching. It has been enhanced and encouraged by many people, whom I'd like to thank for their continued and unending support and assistance.

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journey would have been quite different.

Behind the scenes in all of this is the two men in my life. First, Baby Quayde, you mean more to me than you will ever know. When I look at you, I strive to do right; I want to do and learn more. You have turned my world upside down, and for that, I thank you. And to my husband, Justin, my rock, without you, I do not know where I would be. When I feel it to be most impossible, you believe in me to try. When I feel it to be most uncomfortable, you encourage me to take risks. Thank you for your undying love and support of who I truly am.

Abstract

WRITING IN MATHEMATICS

Livia Doyle

Under the Supervision of Lindsay Hollingsworth

This research study investigated how the use of writing in mathematics, more specifically the use of math journals to record student thinking, communication and mathematical reasoning, affected the competency of written responses by fourth grade students. For this study, students reflected on their mathematical thinking in a math journal, on average, three times a week for six weeks. Data was gathered through identical pre- and post-assessments. A rubric was provided to assess students' written responses. Findings of the study indicated that the use of writing in mathematics proved to strengthen the communication, organization, and mathematical reasoning of written responses; however, no statistically significant outcomes were recorded.

TABLE OF CONTENTS

PAGE

CHAPTER ONE

INTRODUCTION

REFLECTION

From my experience, often times students find it difficult to express how they have unraveled a mathematical equation or problem and the steps and strategies they used to solve it. As I observe and think back to past student writing samples that were completed in or outside of class, more often than not, responses were short, unclear, and included little math terminology. In contrast, when students are asked to verbally explain the process used to solve for an answer, their responses tend to be clearer and more organized. There appears to be a sense of disengagement from mind to paper when students generate written explanations. Reflecting back on these experiences, I am reminded that perhaps I did not find the time to properly teach and demonstrate the importance of writing a clear and organized response, nor did I give the students ample opportunities to improve upon their written explanations. This research study stems from these reflections.

PURPOSE OF THE STUDY

The Smarter Balanced Assessment (SBA) is a highly rigorous, next-generation assessment aligned to the Common Core State Standards (CCSS) and is aimed to measure the depth of understanding, writing and research skills, and complex analysis of each individual student upon completion of this formative, spring assessment. (Smarter Balanced Assessment Consortium, 2014). In 2010, the state of Wisconsin joined the Smarter Balanced Assessment Consortium, a national consortia focused on the implementation of a next generation achievement exam to measure student progress toward college and career readiness. Up until now, the SBA has been in the developmental and pilot phases to ensure assessment questions are flawless and the

technology performs as is intended. During the 2014-2015 school year, all public schools in the state of Wisconsin, have transitioned from the Wisconsin Knowledge and Concepts Exam (WKCE) to the SBA to measure the performance of students, teachers, and schools. Assessments will be administered to students in grades 3-8 in the areas of English Language Arts (ELA) and Mathematics.

It is important to note that in the fall of 2014, Wisconsin changed the name from Smarter Balanced Assessment to Badger Exam as a way to personalize the name of the assessment to the state. This name change does not alter the make-up of the assessment, the test questions, or the manner in which the assessment is evaluated. Throughout this study the name Smarter Balanced Assessment (SBA) will be used to describe this assessment.

The SBA outcomes are tied to high stakes evaluations that directly affect the accountability of Wisconsin educators and schools. Beginning with the 2014-2015 school year, the SBA will serve as the essential achievement test for all public schools in the state of Wisconsin. This achievement test will measure the skills and knowledge among students in the school, compared to national standards. Furthermore schools will be evaluated on student performance of the SBA, which is publicly reflected on school report cards as part of the new state accountability system. (Department of Public Instruction, 2014). To ensure positive results and strong achievement scores, administrators and teachers find it necessary to revisit the Common Core State Standards, their curriculum, and their instructional styles.

The SBA is composed of four parts: selected-response items, technology-enhanced items, constructed-response items, and performance tasks. Looking closely at constructed-response items, student will need to be able to produce text or numerical responses in order to demonstrate their knowledge and understanding of a given assessment target. From these responses, test

reviewers will gauge the critical thinking and problem solving skills of individual students. In order for students to demonstrate their conceptual understanding, procedural fluency, and mathematical reasoning successfully on this new assessment, it is imperative that each student be able to clearly communicate their mathematical processes and use appropriate terminology in explaining their answer.

Many researchers advocate the use of writing and journaling to enhance elementary and middle school students' understanding of mathematics (Baxter, Woodward, & Olson, 2005; Burns, 1995; 2004; Kostos & Shin, 2010). Kostos and Shin (2010) developed a research project in which second grade students used math journals to enhance communication of mathematical thinking. Students wrote in their journals an average of three times a week over a five week period as they responded to prompts that asked them about the mathematical concepts previously taught in class. Data were gathered through pre- and post- math assessments, students' math journals, selected student interviews, and the teacher-researcher's reflective journal. The research findings indicated that the use of math journals helped students to communicate their mathematical thinking as well as use math vocabulary more frequently.

It is important for students to be able to demonstrate their mathematical thinking as well as communicate their method of solving a problem. This research study closely aligned to the work of that carried out by Kostos and Shin (2010), in which pre- and post-assessments were used to determine if the use of math journals have a positive impact on mathematical understanding.

STATEMENT OF THE PROBLEM

The problem is that SBA requires students to respond and communicate their mathematical understanding when solving a problem, but little to no time has been assigned to properly

prepare and teach students how to properly and clearly reflect on their mathematical thinking. When asked to answer a constructed response question and explain their thinking, to what extent will students communicate their mathematical understanding to appropriately and correctly solve for an answer and explain their reasoning?

DEFINITION OF TERMS

Accountability System: a means of assessing performance of all public schools along a rating continuum using multiple measures, which in turn determines the level of support a school receives (http://oea.dpi.wi.gov/accountability, 2014)

Action research: research conducted while engaged in an endeavor

Analytical thinking: ability to articulate, visualize and solve problems quickly and effectively

Analyze: to look at in a critical way, in order to determine the comprehension and reasoning level of a problem

Badger Exam: another name for the Smarter Balanced Assessment adopted by the state of Wisconsin in order to personalize the assessment to our state's history

Common Core State Standards (CCSS): K-12 English Language Arts/Literacy and Mathematics standards that will create a clear, consistent level of knowledge for public school students regardless of where they live (http://www.nea.org/commoncore, 2014)

Constructive response: a written or oral response indicating a students' understanding of the processes involved with the successful completion of a mathematical task

Extended response: (see *constructive response*)

Math journal: a journal/notebook, shared with the teacher, in which students write and record their math work, questions, and thinking

National Council of Teachers of Mathematics: a global organization that serves math teachers and administrators by providing math resources and professional development opportunities

Smarter Balanced Assessment (SBA): next-generation assessment aligned to the **Common**

School Report Card: a report card produced by the Wisconsin Department of Public Instruction, as means of communication, to publicly reveal and share school and district performance material. (http://reportcards.dpi.wi.gov/, 2014)

Core State Standards (CCSS) that accurately measures student progress toward college and career readiness (http://www.smarterbalanced.org/about/, 2014)

DELIMINATIONS OF THE ACTION RESEARCH STUDY

This action research study has been limited to students in my 4th grade classroom in a rural school district located in southwest Wisconsin. The presentation and interpretation of this data was assembled during a six week period in the first quarter of the 2014-2015 school year.

METHOD OF APPROACH

The action research model implemented with my experimental group began with a pre-assessment to measure students' answers on constructed response items in mathematics. Next, math journals were introduced to students as a means of recording and encouraging students to explain their mathematical thinking step by step, using words, diagrams, tables, pictures, etc. Students answered various constructed response items. Journal responses were considered in one the following two ways. Students shared, discussed, and followed the response rubric to build upon and make better their responses or responses were collected, analyzed, and constructive feedback was provided to each student in a one-on-one setting in order to help them improve in their constructed response writing. Data were collected from a

post-assessment identical to the pre-assessment in order to measure the significance of the implementation of math journals.

Furthermore, data collected from the experimental group has been compared to the data collected from a control group, one that was selected because of similar demographics. The pre-and post-assessments were administered by the teacher of the control group during the exact dates and times as assessments were completed by the experimental group. The control group did not keep a math journal, nor did the instructor of the control group encourage students to reflect on their mathematical thinking in the form of writing. Additionally, the experimental and control groups teach mathematics at matching times throughout the morning and identical curricular resources are used in both settings.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Writing in Mathematics

The National Council of Teachers of Mathematics (NCTM), a global organization focused on mathematics education, identifies 10 standards for Pre-K-12 Mathematics, five content standards and five process standards (NCTM, 2000). Among the five process standards is *Communication*. NCTM recognizes that instructional programs from prekindergarten through grade 12 should enable all students to organize and consolidate their mathematical thinking through communication, converse their mathematical thinking coherently and clearly to others, analyze and evaluate the mathematical thinking and strategies of others, and use the language of mathematics to express mathematical ideas precisely. Oral and written communication can be used as tools to assess student understanding, as students are challenged to be clear, convincing, and precise in their use of mathematical language.

The Smarter Balanced Assessment Consortium has designed a national assessment system that accurately measures student knowledge and understanding in the areas of English language arts/literacy and mathematics. (Smarter Balanced Assessment Consortium, 2014). The assessment involves several response formats for mathematics problems: selected-response item, technology-enhanced items, constructed-response items, and performance tasks. This format is different from past traditional state assessments in which only selected-response items were available. Constructed response items will require more analytical thinking and reasoning from students, something many students are uncomfortable with or have little to no experience in documenting their thought processes and reasoning skills.

Benefits

Expressing mathematical thoughts and processes can be a difficult feat for many. Kenney (2005) describes mathematics as a foreign language for most students; it is learned almost entirely at school and often enough is not spoken at home, other than the naming of small whole numbers. Unfortunately this disconnection can serve as a barrier for students when asked to explain their mathematical thought processes, whether they are in or outside of school. Simply providing an answer to a problem, alone, does not demonstrate how students are learning, the strategies being practiced, or the process of how a problem is solved.

Writing should be incorporated across all subject areas as it provides unique evidence that teachers can use to assess understanding. Researchers agree that, like reading, improving student's writing skills improves their capacity to learn (National Institute for Literacy, 2007). Comparable to all things, writing in mathematics must be taught and practiced. Burns (2004) describes in detail a variety of writing assignments she implements daily in her mathematics instruction: keeping journals or logs, solving math problems, explaining mathematical ideas, and writing about the learning process. Using math journals allows students to document their math learning in the chronological order of their learning experiences. The journal can be used to write about what they learned in class, describing a like or dislike in mathematics, sharing a confusion or question they still have, and also to summarize discussions and math explorations that were investigated in class. Students also write about their thoughts and strategies that they used when solving a particular math problem. Students are encouraged to use words, pictures, graphs, etc. to help aid them in their responses. In addition, Burns asks her students to write about a math concept or idea in order to get her students thinking mathematically about what they do know and do not know about a certain area of mathematics.

When students write explanations of their work and give examples, not only can teachers better assess student understanding and progress throughout time, but students themselves begin to make connections and develop deeper mathematical understanding in their own answers. Urquhart (2009) organizes a recent article into three sections to discuss the benefits of writing in mathematics. Section one provides a brief overview as to why write in mathematics. The second section describes ways in which writing is already a part of the mathematics curriculum, and the final section discusses strategies and ideas on how to incorporate writing into the mathematics classroom. Urquhart further states that until she reads what she has written, she doesn't see the holes in her logic, the missing steps, or the rambling thoughts in her explanations. Writing provides time for the student to organize their thoughts, clarify their reasoning, and reflect on their learning.

Using Math Journals to Enhance Communication

Conversing with others, sharing strategies, and writing explanations are ways students can visualize their mathematical thinking and demonstrate it to others. Both writing and talking are tools for collaboration, discovery, reflection, and assessing student understanding of mathematical concepts. Kostos and Shin (2010) developed a research project in which second grade students used math journals to enhance communication of mathematical thinking. Students wrote in their journals an average of three times a week over a five week period as they responded to prompts that asked them to respond to mathematical concepts previously taught in class. Data were gathered through pre- and post-math assessments, students' math journals, selected student interviews, and the teacher-researcher's reflective journal. The research findings indicated that the use of math journals helped students to communicate their mathematical thinking as well as use math vocabulary more frequently.

In a similar study presented by Baxter, Woodward, and Olson (2005), the use of journals was implemented in a seventh grade mathematics class. Students were asked to respond to a variety of open-ended prompts which elicited feelings and opinions about certain math topics and were sometimes asked to demonstrate and explain their mathematical thought processes. Student responses were analyzed using a coding system which identified four levels of student's conceptual understanding. Baxter et al. (2005) demonstrated that writing in mathematics could be used as an alternative form of communication for academically low-achieving students. This writing process can serve as another way for students to respond to mathematical equations, word problems, and ideas. In addition, findings showed that writing served as another way for students to communicate and ask questions with their teacher in a trusting and safe environment, which offered a strong connection and confiding relationship between teacher and student.

CHAPTER THREE

METHODOLGOY

PARTICIPANTS AND SETTING

The setting for my research took place in my fourth grade mixed ability classroom located in a rural school district in Southwest Wisconsin. Approximately 320 students attend this prekindergarten through fifth grade school.

This research study was conducted in my homeroom class of 16 students. Nine students are male and seven students are female. Of these students, one has been identified with an Other Health Impairment (OHI) and has an Individualized Education Plan (IEP). Data has been collected from every student.

I am the teacher of this classroom. This will be my fifth year in education, of which the past four consecutive years have been teaching in grade four.

For comparison purposes of this study, a control group has been selected as a fourth grade classroom with similar demographics. This control group is made up of 17 students, ten boys, seven girls. It is important to note that one student in the control group has been removed from this research study because of cognitive disabilities. This student is unable to complete or make sense of the pre- and post-assessment independently nor with assistance. Therefore, data has been collected from 16 students in the control group.

MATERIALS AND PROCEDURES

Data gathered for this research study was taken between the dates of October 10 – November 21, 2014. Math journaling instruction occurred throughout a 60 minute mathematics block during the morning hours of each day. In the course of this time, students wrote in their math journals on average of two to three times a week reflecting on the main objectives of course material.

Because this study took place during the early part of the year, multiplication concepts were taught. It was from this area that much of the writing took place.

A pre-assessment was administered during the week of September 15th to fourth grade students in my classroom, as well as the control group, to assess students' written responses when asked to explain their thinking. This pre-assessment was composed of three questions, of which all were collected from the SBA Practice Test at the third grade level. For the purpose of this research study, finding the answer to a solution was one small part of the assessment. Rather, the main focus centered on the written thought processes, explanations, and reflections of each problem instead of solely solving for a correct answer. Furthermore, as stated previously, data for this research study was collected during the early part of fourth grade and thus, students have not yet been exposed to content assessed on the fourth grade SBA practice test. For these reasons, questions on the pre- and post-assessment were written at a third grade level to engage all fourth grade students to reason, justify, prove, make connections, and reflect upon their learning and understanding. Data were collected from all students and a rubric was used to assess and analyze responses.

Throughout the six weeks, constructed response questions were given to my students at the beginning, middle, or end of a lesson. These questions were generally taken from several formative assessment pieces from *Math Expressions,* the current math curriculum that serves as a resource in my classroom. Once students had the opportunity to explore and investigate a particular mathematical concept, these constructed response questions assisted as valuable formative assessment pieces where written responses were evaluated to measure the depth of understanding a student had with the corresponding mathematical skill. In return, the writing

process served as great practice for students to think, organize, and create a well addressed response.

For many students the most difficult part of writing a written response was the transfer of thoughts in their brains to the act of writing on paper. The organization of it all seemed to be unbearable for a few. To better support students with this transition, prompts were provided to assist students in forming well thought out, reflective responses. These prompts were given to students in the form of a bookmark for students to review and use as they generated their written response. Response prompts included *My answer shows that…, I know…, I wonder…, A strategy I used is, I connected this to,* etc.

Written responses often resulted in sharing. The thoughts, justifications, and reflections captured in math journals, were shared with partners, small groups, or many times, in a whole group setting. Our document camera was used to project the work completed in the journal up on to our SMART board so all could see. After solutions and thought processes were shared, classroom peers received the opportunity to question and challenge the ideas of what was communicated. Students used what they knew to critique the reasoning of others, if needed, or asked questions of which prompted the student to dig deeper into their explanations. On the backside of their writing prompt bookmark, previously referenced, questioning prompts were included to help students ask meaningful questions which would, in turn, create deep, profound mathematical discussion. Questions prompts included *I agree/disagree with* _____*'s thinking because…, How did you figure out…., Why did you…,* etc. A safe, trusting, and positive classroom atmosphere was essential for students to feel secure and honest to share their intelligences with others.

At the beginning of this study, forming a written response was modeled and discussed during whole group instruction to show students how to clearly organize their responses and explain their thinking. In addition, mini lessons were taught throughout the six weeks that demonstrated the importance of using math vocabulary, providing step-by-step explanations of strategies, and using specific words from the question to begin a written response. Throughout this study's timeframe, students were encouraged to share their responses with a partner, small group, and whole class. Additionally, and most importantly, students always had the opportunity to edit their responses when listening to the thoughts, ideas, and feedback of their classmates.

Math journals were collected two times during this analysis in which I and each student met separately to discuss their written responses. This proved to be a good experience for all involved. The students were clearly able to see that this endeavor was something I was committed to in their success. Students were able to read aloud their response and review the rubric with me to see if they met each of the five criteria points. I provided assistance in their organization of thoughts, coming up with examples and non-examples, and adding additional math vocabulary to create a more accurate and descriptive answer. I was able to see first-hand at how powerful it was for students to read aloud their response. Often times, some of the best corrections and additions were made from oral reading. I was also able to connect with each student's level of understanding and developing early on in the beginning stages of this study.

CHAPTER FOUR

RESULTS

Data Gathering and Analysis

During this timeframe, responses in math journals were informally evaluated. Classroom observations, whole group discussions, and individual and small group meetings were used to informally assess the progress of the reflections and writings of the students. The design of this research study focused on the growth of my students throughout the six week implementation of writing in mathematics. Growth was determined between pre- and post-assessment scores to conclude if mathematical reasoning and written communication improved upon the scores of the latter assessment.

Pre- and post- instructional math assessments were scored using a rubric I developed that modeled the research and findings of Kranz (2012) that reflected mathematical reasoning and communication skills. The scoring rubric consisted of a 0-2 scale with 2 being the most evident in each of the five categories. Categories included (1) *Does the writing convince the reader that the student understands the math concepts?*, (2) *Does each answer include its question?*, (3) *Is there an example or drawing included in each response as supporting information?*, (4) *Is the information clear, correct, and factual?*, (5) *Did the student correctly use math vocabulary in their response*? Pre- and post-assessment scores from the experimental and control group were compared using a paired *t*-test.

In reviewing students' overall growth from the pre-assessment to the post-assessment, results of the analysis indicated that the growth of the experimental group ($M = 9.56$, $SD = 6.93$) was greater than the growth of the control group ($M = 6.31$, $SD = 6.65$), $t(15) = 1.4726$, $p = 0.1615$ ($p > .05$), resulting, however, in no statistically significant outcomes. The mean scores of the

experimental group was 5.8 on the pre-assessment and 15.4 on the post-assessment. Specifically, of the sixteen students, all but 1 student increased their overall score from the pre- to the post-assessment.

When taking a closer look and breaking down the results question by question, almost every student exhibited measures of growth from question to question on the post-assessment. Figures 1-3 break apart each of the three questions from the assessment and shows data from all 16 students (x-axis) in the experimental group. Point value (y-axis) is shown in correlation to each student on the corresponding question.

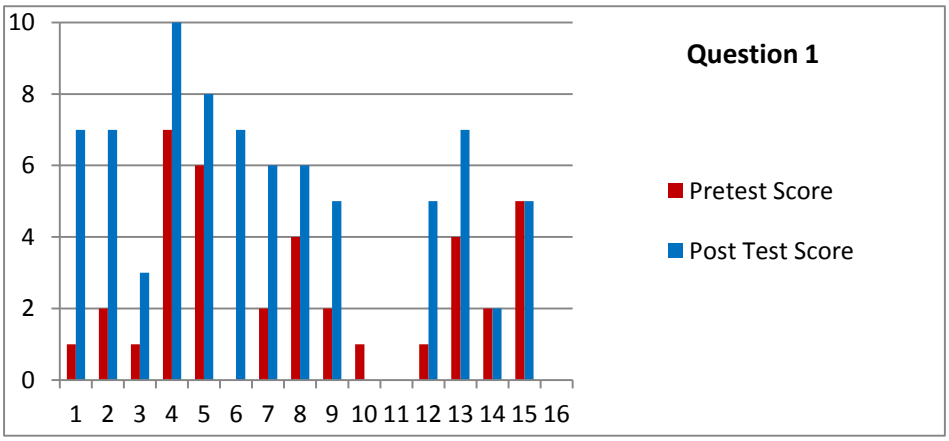

Figure 1: Students' pretest and posttest score for question 1.

The above graph does not show any data for student 11 nor 16, because in both the pre- and post-assessments, the total score for these students was 0.

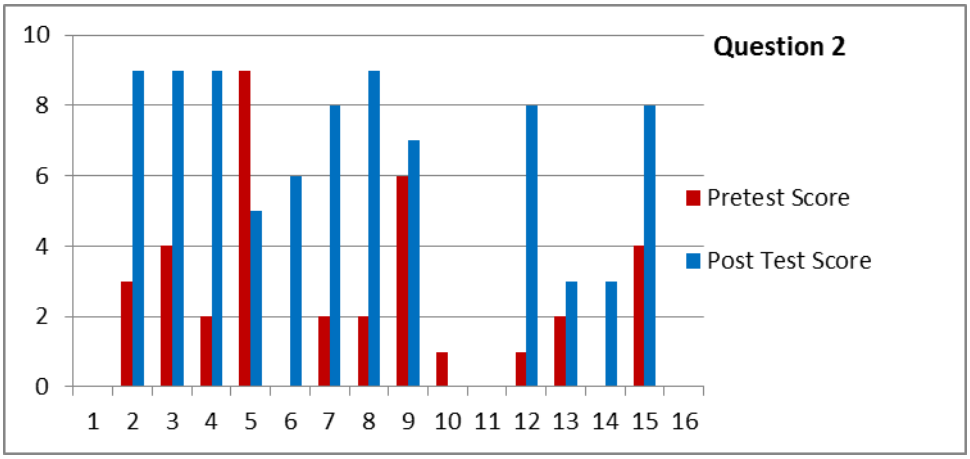

Figure 2: Students' pretest and posttest score for question 2.

The above graph does not show any data for student 11 nor 16, because in both the pre- and post-assessments, the total score for these students was 0.

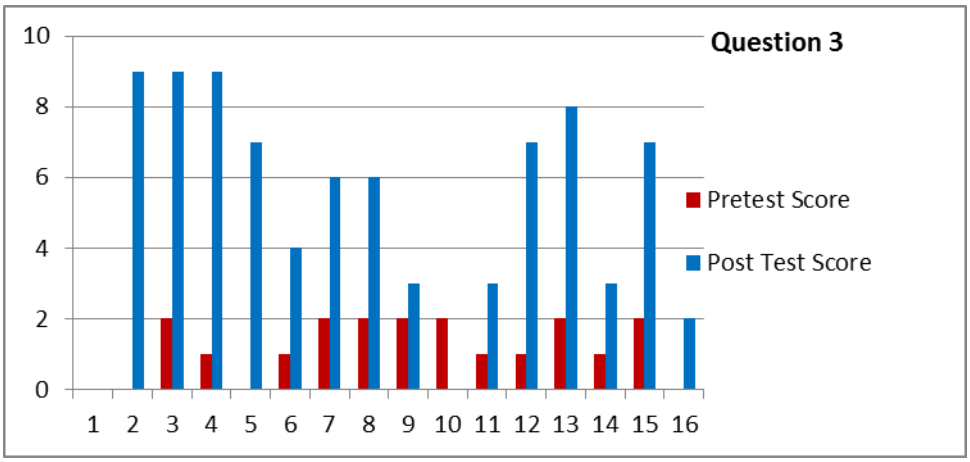

Figure 3: Students' pretest and posttest score for question 3.

The above graph does not show any data for student 1, because in both the pre- and post-assessments, the total score for this student was 0.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

SUMMARY

Based on review of relevant research related to writing in mathematics, conclusions have been drawn based on my findings. This study focused on the written explanations of student work, providing examples to support an answer, making connections and reflecting on mathematical concepts and ideas as a means of communicating mathematical understanding and reasoning to appropriately and correctly solve for an answer.

Although this brief research study comes to a close, the implementation of writing in mathematics is far from over. Instead, writing in mathematics has become a valuable part as to how I teach mathematics in my classroom. Throughout this experience, I find that writing in mathematics is not a one-step, fix all solution to increase student understanding, reasoning, and achievement levels. Rather, it is one of many ways to incorporate student reflections, considerations, reasoning, and powerful discourse in the classroom, which in turn builds and supports strong mathematical minds in all students. Writing in mathematics provides students the opportunity to reflect on their mathematical understanding, create connections across mathematical domains, and analyze and review their thought processes. In addition, and as equally important, students' writing and journaling can serve as a powerful communication tool, and/or perhaps, an assessment tool for all teachers to know and better determine their students' levels of understanding with any mathematical concept and skill.

CONCLUSIONS

After completion of this research study, there are many things that are worthy of discussion. First and foremost, completing this endeavor was a first for me, and it certainly proved to be a

wonderful learning experience. My level of engagement and commitment to critique and prime the learning, explorations, and thought processes of my students was at an all-time, professional career high. I was alongside my students in every step of the way during this journey to support and motivate my students. It must be mentioned that when students first began this journey in mathematical writing, their attitudes were a bit unfavorable, something I am not used to hearing, and the writing process was slow and time consuming. However, over time and practice, their pace began to quicken. Through much discussion and eye opening conversations, the negativity began to dissipate. Students began to see that their minds were so much more than just finding a correct answer. They were able to communicate the hows and whys to a problem that they never once thought was possible. This was an amazing transition to see in the short six weeks of this study. With that noted, however, after conclusion of my first research study, there would certainly be several things I would do differently if I were to begin it all again.

As I began the new school year, I did not anticipate a curriculum change in my mathematics class. Once this research study was in the beginning stages of implementation, an opportunity was brought forward to pilot *Math Expressions* a new math curriculum. This change in venue was certainly welcomed, however not expected. Throughout the course of this research study I did my best to focus my teaching and energies around writing in mathematics, yet at the same time stay truthful to *Math Expressions* and use it to fidelity, which is what is asked for during pilot phases. At times this proved difficult, as with any curriculum pilot, the process can be slow, arduous, and tedious.

As I reflect on the pre- and post-assessment I developed for this study, I honestly admit that I'm not sure if this assessment revealed all that I wished to be reflected. First and foremost, of the three assessment questions, not one of them reflected on the writing we did in class which

focused mainly on multiplication. The three questions were written at a third grade level, so as not to prove difficult in content, and focused mainly on geometry concepts. Regrettably I felt as though this backfired as when reading responses to question number 1, *Identify all the quadrilaterals and explain why you circled the shapes you chose*, it proved to be quite difficult because students were not sure if their explanation of a quadrilateral reflected the true definition. A response that I was in full force trying to avoid! Unfortunately geometry hasn't been reviewed and explored in our new curriculum, so throughout this assessment there were times of uncertainty in student responses.

One challenge I found to be most difficult in this entire study was the large time commitment of writing and reading the responses. Allowing time for students to write, explore, and reflect proved to be taxing in our already tight schedules. In addition, finding the time to read responses was equally trying. I felt it best to read and comment in order for students to receive the feedback to better themselves as a critical thinker and communicator in mathematics. Lastly, I felt it just as imperative to sit and discuss the writing efforts of my students, so I made an attempt to meet with each student twice over the course of this study to openly discuss the quality and challenges of their written responses. Finding the time to meet with each individual student proved to be difficult.

It is imperative that I discuss the six week timeframe of this study, which in my findings has served as too small of a window to fully see the growth and progress of my students. The first half of this research study was dedicated to modeling a well thought out answer to a constructed response question. This took time for students to be able to do independently, and for some students, especially those who find math to be more challenging than others, never reached the point of independently responding to all parts reflected on the student response rubric.

Lastly, it must be mentioned that this research study was written with the goal that all students would be able to communicate their mathematical understanding to appropriately and correctly solve for an answer, which in turn, would deeper their understanding and reasoning of mathematics. The data collected through the pre- and post-assessments shows gains in these areas, however not the gains as expected to see in all student populations. Students entering the classroom with weaker foundational skills still struggled and did not show the gains as fast or consistently as their peers. I intend to address this concern as I continue to implement writing in mathematics, now a part of my teaching practice.

RECOMMENDATIONS

Based on the research findings and student results, writing in mathematics must always remain a part of my mathematical curriculum. It is my intent to inform and share my findings with my colleagues to increase student learning and understanding in mathematics, and I will continue to allow endless opportunities for students to communicate their mathematical thinking throughout all parts of the day. As we move forward with the Smarter Balanced Assessment, I will utilize data brought forth to compare and assess student understanding of mathematics to further inform my daily teaching and interventions.

CHAPTER SIX

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APPENDIX A: IRB PROTOCOL

UNIVERSITY OF WISCONSIN
PLATTEVILLE
INSTITUTIONAL REVIEW BOARD

9/29/2014

Livia Doyle
Sponsor: Joan Riedle
Department of MSE School of Education
University of Wisconsin-Platteville

RE: IRB Protocol #2014-15-03

Project Title: Writing in Mathematics

Approval Date: 9/29/2014
Expiration Date: 9/28/2015

Your project has been approved by the University of Wisconsin-Platteville IRB via a Full Board Review. This approval is subject to the following conditions, otherwise approval may be suspended:

1. No participants may be involved in the study prior to the IRB approval date listed above or after the expiration date.
2. All unanticipated or serious adverse events must be reported to the IRB.
3. All modifications to procedures, participant selection, and instruments used (surveys, consent forms, etc) must be reported to the IRB chair prior to their use. Extensive modifications may require full board approval.
4. If the project will continue beyond the expiration date, then the researcher must file for a continuation with the IRB at least 14 days prior to the expiration date. If the IRB approval for this project expires before approval for continuation is given, then a new protocol must be filled out and submitted. Federal guidelines allow for no exceptions to this rule. Any data collected after the expiration date cannot be used in the study.

If you have any questions, please contact the IRB chair at the address below. Include your protocol # on all correspondence.

Sincerely,

Dr. Barb Barnet
Institutional Review Board Chair
Professor, Mathematics Department
Gardner 451
University of Wisconsin-Platteville
(608) 342-1942
barnetb@uwplatt.edu

APPENDIX B: PROJECT MATERIALS

Principal Consent Form for Research

I. Research Background

Title of the Study: Implementation of Math Journals to Assess Student Understanding and Achievement in Mathematics.

Researcher: Livia Doyle
4th Grade Teacher, Mineral Point Elementary School
Graduate Student, School of Education
University of Wisconsin-Platteville
608.987.0739
livia.doyle@mp.k12.wi.us

II. Description of Research Proposal

I intend to implement the use of math journals in my mathematics class in hopes that it will have a positive impact on students' oral and written communication and use of mathematics vocabulary so that students are better able to respond to constructed response items.

III. Agreement (to be completed by principal)

I, _____, principal of _____school, understand

- the study and what it requires of the staff, students, and/or parents in my school,
- that the privacy and confidentiality of any staff or student will be protected,
- that I have the right to allow or reject this research study to take place in my school,
- that I have the right to terminate the research study at any time,
- that I have the right to review all consent forms and research documents at any time during the study and up to three years after the completion of the study.

☐ I grant permission to the researcher to conduct the above named research in my school as described in the proposal.

☐ I DO NOT grant permission to the researcher to conduct the above named research in my school as described in the proposal.

☐ I understand that data should be released only by the departments that maintain them. My staff and I will not release data to the researcher without prior approval from the Dallas ISD Research Review Board.

_____
Signature of Principal

PARENT CONSENT FORM FOR PARTICIPATION OF HUMAN PARTICIPANTS IN RESEARCH
UNIVERSITY OF WISCONSIN-PLATTEVILLE & MINERAL POINT UNIFIED SCHOOL DISTRICT

1. Purpose: The purpose of this research is to implement the use of math journals in a mathematics class in hopes that it will have a positive impact on students' oral and written communication and use of mathematics vocabulary so that students are better able to respond to extended constructed response items.

2. Procedure: Your child will be asked to respond to mathematical prompts, provided by the teacher, in their math journal. Each response will be evaluated using a rubric to assess student's depth of knowledge. PARTICIPATION IS VOLUNTARY AND HE/SHE WILL BE ASKED TO GIVE HIS/HER ASSENT. YOUR CHILD'S NAME WILL NOT BE RECORDED ON THE RESEARCH MATERIALS NOR WILL IT BE INCLUDED IN OUR DATA SET OR IN ANY REPORTS ABOUT THE PROJECT.

3. Time Required: 2014-2015 school year

4. Risks: No short-term or long-term risks are foreseen.

Benefits: Having students demonstrate their mathematical thinking and communicate strategies and methods used to solve for an answer is necessary to assess mathematical proficiency. Communication can encourage students to explain how they solved for an answer. This demonstration of critical thinking and problem solving skills will provide instructors, school administers, and national assessment consortia a deeper understanding into a student's thought processes.

5. Your Rights as the Parent of a Student Participant: The information gathered in this study will be confidential. Data or summarized results will not be released in any way that could identify you or your child. If your child would like to withdraw from the study at any time, he/she may do so without penalty or repercussions. The information collected from your child up to that point would be destroyed if you or he/she so desire. If you have any questions, please ask:

Livia Doyle
4th Grade Teacher, Mineral Point Elementary School
Graduate Student, School of Education, University of Wisconsin-Platteville
608.987.0739, livia.doyle@mp.k12.wi.us

Once the study is completed, you may request a summary of the results by contacting the above researcher or Principal Brad Brogley. If you have any questions about your child's treatment as a participant in this study, please call or write:

Barb Barnet
Chair of the UW-Platteville IRB
(608) 342-1942
barnetb@uwplatt.edu

Brad Brogley
or Mineral Point Elementary Principal
608.987.0710
brad.brogley@mp.k12.wi.us

____ DO give consent for my child to participate in the research.
____ DO NOT give consent for my child to participate in the research.

Please print your child's name (First, Middle, Last):_____

Please print your full name (First, Middle, Last): _____

Signature: _____ Date: _____

Please return this completed form to Mrs. Doyle by _____

Student Assent Form for Participation in Research
University of Wisconsin-Platteville
Mineral Point Unified School District

Dear 4th Grade Student in Mrs. Doyle's Homeroom Class,

We want to provide the best education possible to you and future students. Therefore, we are conducting this research project. You are invited to participate in this research project on the implementation of math journals in math class.

The purpose of this study is to use math journals as a tool to explore your depth of knowledge in understanding mathematics and the use of math vocabulary in your responses.

You are being asked to participate in this study because as your teacher, it is necessary to assess your reasoning and mathematical understanding, so that I am able to modify my instruction to better fit your academic needs.

Participation in this study will have absolutely no impact on your grades. The information gathered in this study will be used to assess whether or not the use of math journals helps to improve students' constructed responses.

Your parents have already given permission for you to participant in our research project and we are hoping that you will agree to participate. Your voluntary completion of the study constitutes your agreement (assent) to participate. Thank you for helping us to better help you.

Sincerely,

Livia Doyle
4th Grade Teacher, Mineral Point Elementary School
Graduate student, School of Education
University of Wisconsin-Platteville
608.987.0739
livia.doyle@mp.k12.wi.us

Brad Brogley
Mineral Point Elementary Principal
608.987.0710
brad.brogley@mp.k12.wi.us

Colleague Consent Form for Research

I. Research Background

Title of the Study: Implementation of Math Journals to Assess Student Understanding and Achievement in Mathematics.

Researcher: Livia Doyle
4th Grade Teacher, Mineral Point Elementary School
Graduate Student, School of Education
University of Wisconsin-Platteville
608.987.0739
livia.doyle@mp.k12.wi.us

II. Description of Research Proposal

I intend to implement the use of math journals in my mathematics class in hopes that it will have a positive impact on students' oral and written communication and use of mathematics vocabulary so that students are better able to respond to extended constructed response items.

Participants in the experimental group will be enrolled in Livia Doyle's 4th grade class at Mineral Point Elementary School for the 2014-2015 school year.

In addition, de-identified data will be collected from Lynn Ross' 4th Grade class. Mrs. Ross will use a provided spreadsheet that includes no individually identifiable information. Thus, the information will be de-identified. Those data will be compared to that from the experimental group.

This information will be described as a "fourth grade classroom chosen because of their similar demographics" in any presentations or written reports about my project.

III. Agreement

I, _____ , 4th grade teacher at Mineral Point Elementary School, agree to take part in this research study by means of providing data for a control group. I understand the study and what it requires of the staff, students, and/or parents in my school. Additionally, I understand that the privacy and confidentiality of any staff or student will be protected.

_____
Signature of Participating Colleague

_____
Signature of Researcher

_____
Signature of Principal

Response Rubric

Not Evident	Partially Evident	Very Evident	Name:
0 points	**1 point**	**2 points**	
			Does the writing convince the reader that the student understands the math concept?
			Does each answer include its question? (CSIQ) CSIQ – **C**omplete **S**entence **I**ncludes (parts from the) **Q**uestion
			Is there an example or drawing included in each response as supporting information?
			Is the information clear, correct, and factual; is it easy to understand?
			Did the student correctly use math vocabulary in their response?
	Total Points		

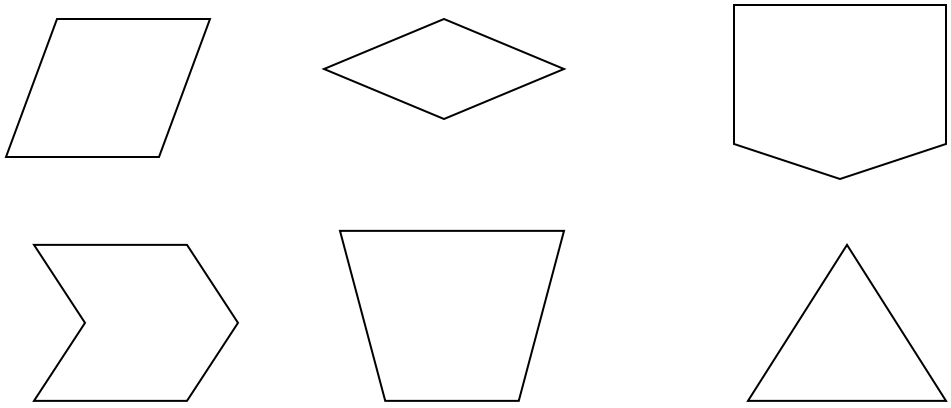
Notes:

PRE- POST-ASSESSMENT

Name _____ Date _____

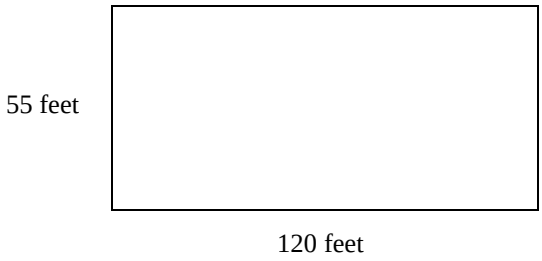
Directions: Answer each question. Explain your thinking and label your answers.

1. Circle all of the shapes that are quadrilaterals.



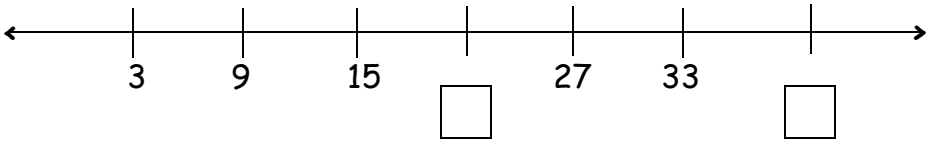
Explain why you circled the shapes you did.

2. A city park is in the shape of a rectangle. The park is 120 feet wide and 55 feet long.



What is the perimeter of the park? Explain how you found your answer.

3. What unknown numbers complete the pattern on the number line?



Explain how you solved for the answers.