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Writing in Mathematics to Increase Student Understanding

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Abstract

The purpose of this action research study was to understand the impact of introducing writing into the math sequence of a third-grade class. The teacher-researcher sought to understand students' perceptions of as well as her personal perceptions of introducing writing into math and how this impacted student achievement. Data was collected through writing samples, assessment scores, observations and reflections, surveys, and interviews. The data was analyzed using the constant comparative method as well as quantitative methods of analysis. Three major themes emerged from the qualitative analysis of the data: process of introducing writing into math, student attitudes and ideas, and developing mathematical understanding. The analysis of students' assessment scores showed that four students' achievement increased. This study will enable educators to gain a better understanding of what it looks to introduce writing into the math sequence of a classroom as well as how it impacts students' perceptions and achievement.

Writing in Mathematics to Increase Student Understanding

“Why do I have to show my work? I got the right answer. Why does it matter *how* I got my answer? I got it right. I can’t explain how I did it. I just did it and got the answer.” I would be willing to bet that most classroom teachers have heard these phrases before, and, to be really honest, I even remember saying some of these things to my teachers when I was growing up. Traditionally, mathematics instruction focuses on calculating the correct answer and places the majority of the attention on the end result. However, the National Council of Teachers of Mathematics (NCTM) encourages teachers to focus on the process, and one of the five process standards developed by the NCTM is communication (Van de Walle, Karp, & Bay-Williams, 2016). Teachers not only have to teach their students the processes of doing math, but they also have to give their students the skills necessary to be able to communicate their understanding. This job is easier said than done. However, some teachers have been incorporating writing into their daily math routine in order to help their students gain a deeper understanding of math concepts as well as to give their students a way to communicate that understanding.

Purpose

The purpose of this study was to understand the impact of using writing in math as a way to gain an understanding of mathematics concepts. I aimed to understand my students’ perceptions regarding writing during math. In addition, I examined my own perceptions about the process of introducing the use of writing into math. Finally, I sought to understand what impact the act of writing in math has on student achievement. The research questions that inspired this study included the following: What happens when a clinical teacher introduces writing as a way to help students develop an understanding of math concepts?

Sub Question 1: What are my students' perceptions about using writing to develop an understanding of mathematics concepts?

Sub Question 2: What are my perceptions as a clinical teacher about the process of introducing the use of writing into math as a way to help students develop an understanding of mathematics concepts?

Sub question 3: How does the act of writing in math, as a way to develop an understanding of mathematics concepts, impact end of unit math scores?

During the study, I was a graduate student completing my yearlong clinical teaching experience as part of the master's program at my university. This study was conducted at Fremont Elementary (all names have been changed to pseudonyms) in a West Texas town with a population of around 120,000 people. Fremont Elementary was one of fourteen elementary schools in the Caldwell Independent School District. Each elementary school in the district was identified as a Title I school. The portion of the student population at Fremont Elementary that was economically disadvantaged was higher than the district's percentage as 75% of the student population was economically disadvantaged.

Related Literature

Incorporating writing into math has been found to have several positive impacts on students. One positive effect of writing in math is increased student achievement. Kostos and Shin (2010) found that students' assessment scores and use of math vocabulary increased after writing in their math journals for five weeks. In addition to influencing student achievement, the use of writing in math has been found to increase student participation. Baxter et al. (2005) concluded that students who typically did not engage in class discussions, in a class where writing in math was routine, did meaningfully participate in writing about math. Teachers,

researchers, and teacher-researchers have noticed these positive impacts, but they are not the only ones. Jurdal and Abu Zein (1998) concluded that, when given the opportunity, students expressed positive attitudes towards writing in math journals. Albert (2000) found that students believed writing in their math journals made math easier.

What contributes to these positive impacts? Writing in math enables students to think reflectively and communicate their understandings, and it allows teachers to see what their students understand. John Dewey (1933) made the claim that thinking reflectively is the best way to think because it deepens one's understanding. The act of writing requires this kind of reflective thinking. The writing samples collected and analyzed by Pugalle (2001) indicated that students were using metacognition and became aware of their own thinking as they wrote about mathematics. The NCTM encouraged teachers to focus on teaching the process of doing mathematics by helping students communicate their understandings (Van de Walle et al., 2016). Students have to make their understandings known to others. Baxter, Woodward, and Olson (2005) concluded that writing in math gave students the opportunity and the skills necessary to be able to communicate their understandings to their teachers. Dewey (1933) explained that teachers are responsible for knowing what their students understand. After looking at how effective the use of math journals were in a second grade classroom, Kostos and Shin (2010) concluded the teacher was able to adjust her instruction for individuals and the whole class after reading students' math journals.

What does writing during math actually look like in a classroom? Math journals are a popular way to incorporate writing into the routine of a classroom's math sequence. Wilcox and Monroe (2011) explained that learning logs, or math journals, can serve as a valuable, meaningful way to begin or end a lesson. Burns (2004) described eleven strategies for utilizing

writing in math including establishing a purpose, using prompts, providing time for sharing, posting vocabulary, and establishing an audience. Jurdak and Abu Zein (1998) utilized two types of prompts in their study including cognitively oriented prompts that focused on mathematics concepts and affectively oriented prompts that focused on students' strategies, explanations, and feelings. Writing a letter to a friend who was absent in order to teach their friend what he or she missed or writing to someone who was struggling to understand a specific math concept are additional prompts used in a separate study (Shield & Galbraith, 2009). Several researchers have used math journals in their studies as a way to incorporate writing into the routine of a classroom's math sequence (Baxter et al., 2005, Jurdak & Abu Zein, 1998, Kostos & Shin, 2010, Shield & Galbraith, 2009).

Previous research studies have found positive aspects to writing during math, shown how writing during math impacts students' understandings, and suggested several strategies for incorporating writing into math. Most of the research studies regarding writing in math include participants in middle school and high school (Albert, 2000, Baxter et al., 2005, Jurdak & Abu Zein, 1998, Pugalee, 2001, Shield & Galbraith, 1998). My study will add to the current body of research by looking at how writing during math impacts elementary students. While other research studies have focused on either academic achievement or the perceptions of students, this study will provide teachers with a better understanding of both students' perceptions of writing during math as well as my perceptions of introducing writing into math for the first time in addition to student achievement.

What I Did

The following describes a mixed-methods action research study conducted in a third-grade classroom. The study was completed during the second semester of the school year. The

students were comfortable with my presence in the classroom as a teacher and a researcher because this was part of my yearlong clinical teaching placement. The students were used to writing and math, but writing in math was completely new. As I introduced writing into the routine of our math sequence, I set the expectations for writing in math and modeled how to respond to each prompt.

Participant Selection

There was a total of 22 possible participants coming from one self-contained, inclusion classroom. The class was ethnically diverse and included 15 boys and seven girls. Three students were receiving accommodations and modifications through their Individualized Education Programs for ELAR as well as math instruction. These students were not asked to participate because they were not in the classroom at the time of our math sequence. Therefore, they did not have the opportunity to write during math. Two students were receiving accommodations as documented on their Behavior Intervention Plans. Additionally, two students were receiving academic accommodations through pull-out tutoring programs.

Every student, with the expectation of the three students being pulled out during the math sequence, was informed of the study and received an informational letter and consent form for their parents to read and sign. Each student who received consent was given the opportunity to fill out an assent form in class. Every student receiving consent and giving assent to participate in the study completed a survey, was observed, and had their assessment scores and writing samples collected. Students were then selected to participate in the interview portion of the study based on their responses to the survey questions.

Data Collection

Several forms of data were collected including writing samples, assessment scores, observations and reflections, surveys, and interviews. Data was collected through samples of students' writing in the form of math journal entries. Students were asked to write journal entries two times a week for four weeks by responding to a teacher-given prompt. Data was also collected through weekly assessment scores. The students' scores on the end of week assessments were collected. Scores were collected on the four assessments prior to the introduction of the use of writing in math. In addition, student scores were collected on the four assessments taken during the four weeks students were writing in their math journals. The students' scores on a total of eight end of week assessments were collected.

Additionally, data was collected in the form of observations and reflections. I kept a reflection journal throughout the study. I wrote in my journal each day the students were asked to write in their journals. I observed the students during our math sequence and wrote field notes that briefly described significant events regarding how the students were responding to writing during math (Hendricks, 2017). I fleshed out my head notes and recorded my reflections after reading the students' journal entries at the end of the day. The reflections were based on general observations during the mathematics lessons as well as the students' writing samples.

Data was also collected in the form of student surveys. The students responded to ten statements by marking an answer on a four-point Likert Scale. The survey also included three open-ended questions about the students' past experiences with writing in math as well as their initial perceptions about writing in math. The surveys were completed during the third week after the introduction of writing in math as a way to better understand mathematics concepts.

Finally, data was collected through student interviews. Six individual student interviews were conducted. The interviews were conducted utilizing a semi-structured interview format

(Hendricks, 2017). The same planned questions were brought to each interview, but the questions varied and additional questions were asked depending on the answers of the participants. Each interview lasted approximately 10-15 minutes, and all interviews were conducted during the fourth week after the introduction of writing into our math sequence.

Data Analysis

The constant comparative method (Hubbard & Power, 2003) was used to analyze students' writing samples, my reflection journal, the open-ended questions on surveys, and interviews. I identified major themes as well as supporting codes after the initial coding. Approximately 15-20 level I codes were identified after manually coding the first 20 percent of the data. The level I codes were then used to analyze the remaining 80 percent of the data. After looking closely at my level I codes, I created level II codes based on the major themes I identified (Tracy, 2013). The level I codes were descriptive and focused on answering the who, what, when, and where questions about the data. The level II codes included my interpretation of the data and focused answering the why and how questions about the data. I created a codebook (see Appendix A) that lists all of my level I and level II codes as well as definitions and examples of each code. I was able to gain an even deeper understanding of my level II codes by writing memos for each one that included my reflections and understandings of each level II code (Tracy, 2013).

The closed ended questions on the surveys were analyzed based on the answers students gave to each question. The students responded to each statement on the survey by marking that they strongly agreed, agreed, disagreed, or strongly disagreed with the statement. Each statement was worded so that "strongly agree" always indicated the most positive perception and "strongly disagree" always indicated the most negative perception of using writing in math. Four

percentages were calculated for each student. One percentage was found for the amount of times they chose each of the four answer choices. Based on this analysis, six students were interviewed: three students with positive perceptions and three students with negative perceptions about the use of writing in math.

The students' assessment scores were analyzed by calculating measures of central tendency (Hendricks, 2017). Individual student scores were calculated by finding the percent of questions students answered correctly. The individual student scores were then used to calculate a mean, median, mode, and range of scores for the four assessments taken before and then for the four assessments taken after writing was introduced into the math sequence.

What I Found

There were three major themes that emerged from the analyses of students' writing samples, students' survey responses (The survey questions can be found in Appendix B, and the survey results can be found in Appendix C.), student interviews, and my personal reflection journal: process of introducing writing into math, student attitudes and ideas, and developing mathematical understandings. In addition to discussing each of the key themes, I will describe the significant findings found from the analysis of students' assessment scores.

Process of Introducing Writing into Math

The idea of establishing procedures and expectations continued to emerge throughout my data. Although this was definitely more prominent during the first couple of weeks of my study, establishing procedures and expectations continued to appear in the data until the very last day I collected data. I wanted writing in math to be consistent and become a routine. Throughout my study, I continued to implement the direct instruction, guided practice, and independent practice portions of the math sequence the same way I had since the beginning of the school year. When I

introduced writing into the math sequence, I did so right after the independent practice portion of the math sequence. I called the students to the rug, our whole group meeting area, and asked them to bring their math journals. Once everyone was seated on the rug, I read the writing prompt aloud and showed my students an example of my writing responding to that specific prompt. Then, I gave the students between five and seven minutes to write. After writing, my students left their math journals open to the page they were writing on and stacked their journals on the back counter where they usually turn in their work. At the end of the school day, I spent about ten minutes reading all of their responses. I used the information I learned about their understanding of the math concept to make adjustments to my lesson plans for the following day. My students and I followed this procedure for writing during math two days a week, Tuesdays and Thursdays, for four weeks.

In addition to having a defined procedure, I wanted to establish specific expectations. It was important to me that my students knew what I expected of them as we wrote during math. I wanted my expectations for their behavior as well as for their quality of writing to be clearly communicated. The behavior expectations for writing during math included staying in your spot and being at a voice level zero. I explained that these two behavior expectations were important so that everyone would be able to concentrate and do their best work. The last behavior expectation I had for my students was keeping their pencil on their paper the whole time. I explained that this expectation was important because I was not giving them a lot of time to write. I continued my explanation by telling my students that there was a lot of information they knew about math, and they needed all the time they could get in order to be able to write it all down. The expectations for their quality of writing included not worrying about spelling or punctuation, focusing on getting all of their thoughts down on paper, and having the option to

include examples. I communicated these expectations clearly by walking my students through my example writing. I pointed out my misspelled words, my numbered lists, my picture examples, and my labels for each picture. The importance I placed on establishing procedures and expectations became very apparent to me as I analyzed my data. I spent a lot of my time explaining the procedures and expectations to my students as well as reflecting on these aspects of my research study. I believe that spending the time to set a firm foundation of procedures and expectations helped me to have more positive experience introducing writing into math because it gave me structure, consistency, and stability.

Along with establishing procedures and expectations, the writing prompt, showing examples, and giving students additional prompting became very important to the process of introducing writing into math. Each time the students were asked to write in their math journals, they responded to a prompt either about a friend who was absent or a friend who didn't understand a concept. A full list of writing prompts can be found in Appendix D. I noticed that the students became familiar with these prompts and took ownership of having the opportunity to help a friend. David explained that he felt excited about writing during math "because last time we wrote, Erica and Abigail were absent, and now anyone in the class can share their different writing with them and how they do it in their steps." Showing students examples of my writing made a positive impact on the process of introducing writing into math. My examples showed my students what it looked like to write during math as well as what I was expecting of them each time I asked them to write. When the writing prompt and my examples fell short of what my students needed in order to start writing on their own, I gave them additional prompting. My additional prompts were given verbally and almost always included questioning. I would ask my

students to define math vocabulary or explain math concepts verbally. After they were able to say the information verbally, it became easier for my students to write about the information.

I have come to understand that the process of introducing writing into math is a continually evolving process. My reflection journal was filled with descriptions of a chaotic classroom, of confused students, and of a clinical teacher who seemed to be in over her head. These less than picture-perfect situations gave me the opportunity to adjust the process of writing in math. I rephrased directions, clarified the purpose, implemented additional scaffolding, and changed the procedures on more than one occasion. With adjustments, the process became smoother and more refined. Although there were times that I was overwhelmed with the process of introducing writing into math, I quickly became familiar and comfortable with the process. I appreciated that the process of introducing writing into math was flexible. The flexibility of the process enabled me to make the decisions, changes, and adjustments necessary for integrating writing into the math sequence of the classroom in a way that was meaningful, productive, and practical for both me and my students.

Student Attitudes and Ideas

The students' attitudes and ideas were either explicitly stated by the students or inferred by me through their actions and writing. I inferred my students' attitudes about writing during math by observing their behavior. Some students avoided writing by getting up during the writing time, playing with their pencils, talking to their peers, and even sleeping. While those behaviors indicated to me a negative attitude, other students wrote quickly, continued writing after the time was up, and wrote without looking up or talking to anyone else. These behaviors showed me that the students were eager to write. Student confusion and student confidence was identified by the students' verbal responses. Some students asked questions about the concepts

and procedures indicating that they were confused, while other students showed their confidence by explaining how easy it was. By observing the students and listening to them, I was able to gain a better idea of students' perceptions towards writing in math. As the students wrote, I observed many students pause to look up and reference the writing prompt. Having the writing prompt available seemed to help students when they felt stuck or couldn't think of anything else to write. However, even though students referenced the prompt, I often heard the phrase, "I'm done." The students were positive that they had written absolutely everything they knew about the specific math concept mentioned in the prompt. If I didn't hear that phrase, I heard, "I don't know what to write." Students who said this felt like they were stuck. They either didn't know how to begin their written response or didn't know how to continue it. The students speaking these phrases seemed to have a negative attitude towards writing in math and were not motivated to persevere through the writing period. I often felt at a loss hearing these phrases from my students. I was not quite sure how to respond. However, I found that engaging the students in conversations about the math concepts increased their confidence and ability to continue writing. Although I had hoped all of my students would have had nothing but positive attitudes and perceptions towards writing in math, finding a strategy that enabled my students who were unmotivated and frustrated be successful enabled me to have a more positive attitude.

As I interviewed students, I quickly became aware of both the good feelings as well as the bad feelings students had as they wrote during math. Some students felt relaxed, confident, and excited about having the opportunity to write while other students felt anxious, bored, and unmotivated. Similarly, there were times when I felt confident, empowered, and enthusiastic about introducing writing into math while at other times I was overwhelmed, frustrated, and perplexed. Martin had a difficult time picking one favorite part about writing in math, so he

explained “I don’t really have a non-favorite part. I like all about it. There’s nothing I really don’t like about it.” However, those positive feelings were not shared by everyone. Jacob explained that, if he were a teacher, he would never ask his students to write during math, “because writing during math sometimes could get boring...just sitting there and just picking up a pencil and write, write, write.” These good and bad feelings influenced the students’ ideas about writing during math. Their ideas about writing in math included specific aspects that they felt needed to change as well as components that they thought could stay the same. Students wanted to change the amount of time we wrote and where we wrote, but they wanted the writing prompts and my writing examples to remain consistent. Gaining a more accurate understanding of my students’ attitudes and ideas towards writing in math enabled me to evaluate the way I introduced writing into the regular math sequence of the classroom. There were components that the students did not like, aspects that the students tolerated, and elements that the students looked forward to. I was thankful that there was flexibility in how I implemented writing in math. This enabled me to adjust the process in response to my students’ attitudes and my own attitudes. The flexibility to adapt the process to meet the specific needs of my students and myself was one of the most exciting and meaningful components of introducing writing into math because I felt as though it made a deeper and more profound impact on the whole classroom.

Developing Mathematical Understandings

Developing mathematical understanding included the key ideas of the purpose of writing as well as remembering and understanding. The purpose of writing was not only something that I explicitly explained to my students but also something that my students brought up in their interviews. I explained that the purpose for writing in math was for all of us to know what they really knew about the math concepts they were writing about. I elaborated on this idea by

describing that the purpose for writing in math was to slow down and think about what we really know and share our math thinking to others. My students explained that the process of writing showed them what they knew and made them realize what they didn't fully understand yet. Gabe explained the purpose of writing in math when he described that writing in math is important "because then we can understand math more and learn about it more and teach other people." Remembering and understanding was a theme that emerged from the student interviews. The students described how writing about math helped them remember the concepts when they saw questions later. Steven explain that writing during math "helps me remember it...I can look back on the paper or math journal." My students made it clear that they understood the math concepts better and more fully after they wrote about them. Natasha described how writing during math helps her understand math concepts "because once you write, you can comprehend stuff way better...because once I write, it helps me understand more stuff that I need to know." My motivation behind this research project was to increase my students' understanding of math concepts. I was excited to see that my students understood and valued this purpose too. Seeing that my students believed in the benefits of writing during math gave me a deeper appreciation for the entire process of introducing writing into math.

Through examining the students' accurate written responses, the examples they included in their writing, and their inaccurate written responses, I was able to see that my students' writing mirrored what they described in their interviews. Their second writing each week seemed to be more accurate and more thorough than their first. Looking specifically at their written accuracies, inaccuracies, and examples, I was able to gain a deeper understanding of how my students' mathematical understanding of concepts was developing. For example, Natasha defined equivalent fractions as "fractions that may look different but are equal to each other." She also

included an example as shown in Figure 1. Her written response was very similar to many other students' responses. By reading their responses I knew that I did not need to spend more time on the definition of equivalent fractions. I was able to see that I now needed to give my students the opportunity to apply their knowledge of equivalent fractions to a variety of different contexts. In contrast to accurate written responses, Steven described one part of a division problem as the "dividend is a times answer." After reading several other students' responses that were similar, I knew that I needed to spend more time defining and describing the parts of a division problem before I moved on to having the students apply this knowledge. Being more attune to my students' mathematical understanding, had a positive impact on my future instruction. I was able to adjust my instruction to meet the immediate, specific needs of my students. Having this ability was, for me, the most meaningful component of introducing writing into the math sequence of the classroom.

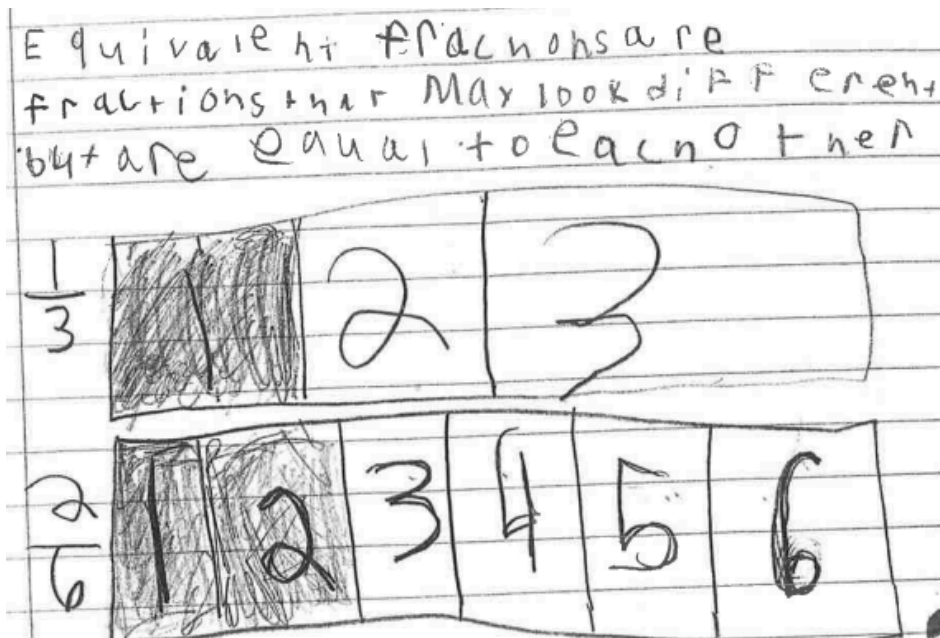


Figure 1. Natasha's writing sample.

Assessment Scores

I compared the mean of students’ assessment scores from the four weeks before I began introducing writing into math to the mean of students’ scores during the four weeks students were writing during math. During weeks one, two, three, and four the mean scores were 71.67, 74.83, 83.85, 69.83 respectively. The mean score for the four weeks students were participating in math the same way that had been since the beginning of the school year was 74.98. During weeks five, six, seven, and eight the mean scores were 66.75, 67.50, 67.42, and 80.90 respectively. The mean score for these four weeks was 70.64. During these four weeks, the students were writing twice a week. The mean score on students’ assessment decreased 4.34 points during the implementation of writing during math.

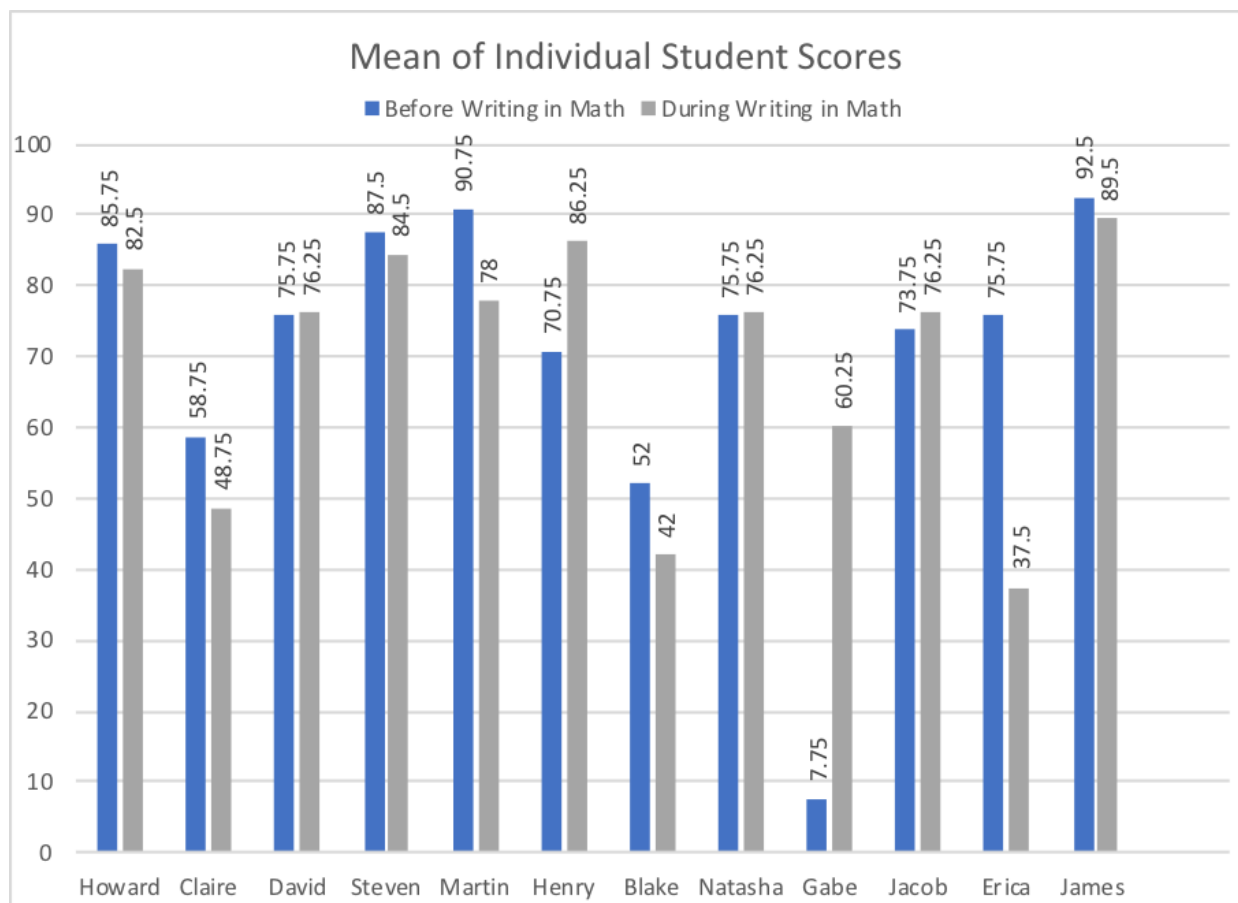


Figure 2. Graph of students’ assessment scores.

In addition to studying students' assessment scores by week, I examined the assessment scores of individual students before and after the introduction of writing into math. Eight students' scores decreased after the introduction of writing during math. Erica's scores decreased the most. Her mean score on the assessments before writing during math was 75.75 while her mean score during the implementation of writing during math was 37.50. Her mean scores decreased by 38.25 points after she started writing during math. Four students' assessment scores increased after they began writing during math. Henry's scores increased the most. His mean score on the four assessments before writing during math was 70.75, and his mean score increased by 15.50 points to 86.25 when he began writing during math. In Figure 2, you can find the mean scores for each individual student, and all of the students' assessment scores can be found in Appendix E.

There are limitations to analyzing students' assessment scores. We covered a different math concept each week. During the four weeks before I introduced writing into math we covered multiplication with no regrouping, multiplication with regrouping, area, and equivalent fractions. During the four weeks students were writing during math we covered equivalent fractions in sets of objects, place value and multiplication, problem solving strategies, and division. Another limitation of analyzing students' assessment scores was other factors that could have potentially impacted students' scores. During my study a lot of students were absent. Some students were only absent once while some students were absent multiple days within the same week. There were also several students who were absent on one or more Fridays during the study. When students missed the assessment on Friday, they had to wait three to five days to take the assessment. The increased time between the instruction and their assessment as well as missing the instructional time spent on the math concepts could have impacted their assessment

scores. Because students were assessed over a different concept each week and there were outside factors that could have impacted students' assessment scores, it is difficult to determine the extent to which students' assessment scores were impacted specifically by the act of writing during math. Initially, I was disappointed not to see a dramatic increase in students' assessment scores. However, I had to remember that there were still, as there always will be, factors that were outside of my control. I believe that the process of introducing writing into math was a good first step in helping my students gain a deeper understanding of math concepts. I hope to have the opportunity to continue collecting and analyzing data in order to find more trends and make adjustments to the process that will ultimately result in my students having the ability to not only increase their assessment scores but also to comprehend the mathematics concepts at a deeper and more meaningful level.

Implications for Teachers

Traditionally mathematics instruction has focused on preparing students to calculate an accurate answer. Recently the conversation within the educational community has shifted to not only asking students to produce a correct answer but also requiring students to explain their process. Writing in math enables students to think reflectively and communicate their understandings, and it allows teachers to see what their students understand. Previous research studies have shown that writing in math has been met with positive attitudes from teachers, teacher-researchers, and students as well as increased student achievement. In contrast to the majority of other research studies, my research was conducted with elementary school students. However, my study produced results that were similar to the previous research studies conducted with middle school and high school participants.

Although not all of my participants' achievement increased based on the analysis of their assessment scores, several students' scores did increase. I think that there were many factors that could have contributed to seeing increased achievement in some students and decreased scores from other students. Students' assessment scores could have been impacted by the number of absences students had during the week, their attitude on the day the assessment was given, and how focused they were as they took the assessment. In addition, I believe that the students whose scores decreased may have benefited from additional time practicing the math concept, while the students whose scores increased benefited from being able to engage in reflective thinking and write. Writing during math did take away between five and ten minutes of instructional time during our math sequence two days a week. It is hard to determine how much of the students' assessment scores were impacted specifically by introducing writing into math.

Personally, I consider my most significant finding to be the emergence of developing mathematical understanding as a key theme. I was able to see, through the data I collected, that my students believed writing during math helped them understand and remember the concepts better. I had the opportunity, from looking at my students' writing samples, to gain a more detailed picture of exactly what my students understood and what concepts still caused confusion. Developing mathematical understanding was the goal from the very beginning. The data I collected and analyzed provided evidence that writing during math can help my students develop mathematical understanding as well as enable me to provide my students with more meaningful instruction.

As teachers begin to introduce writing into the math sequence of their classrooms, I would encourage them to be flexible. Although writing during math became a routine in my classroom over the four weeks, I am still making minor adjustments to the process as I continue

to make writing in math a priority in the classroom. It took me about a week to find a routine that worked well for my students as well as myself. Writing during math may look different in each classroom, and I think it should. It is important to, like you would with any new instructional practice, take the time to find what will make your students successful. In addition, it is important to understand your students' perceptions towards writing during math. I found that some students really enjoyed writing during math while other found it boring. In the future, I will be exploring ways to make it more engaging for all of my students. I am hopeful that introducing writing into math from the very beginning of the school year and allowing students to provide input into how it is implemented will cause students to really take ownership in the process.

Although this research study is informative, important, and influential to the educational community, I am still left with questions about how writing during math impacts students, student achievement, and teachers. How much of student achievement is impacted solely on the act of writing during math? How can teachers make writing during math engaging for all students? How much instructional time should be dedicated to writing during math?

Writing during math gives students the opportunity to reflect on their personal understanding of math concepts as well as communicate their understanding to others (Dewey, 1933, Pugalle, 2001). In addition, I found that writing during math enables teachers to gain a deep understanding of what their students know as well as become aware of any misconceptions their students have. Students have been found to have positive perceptions towards the act of writing in math (Jurdal & Abu Zein, 1998). Writing in math has been found to not only increase students' understanding of math concepts but also increase students' mathematical achievement (Kostos & Shin, 2010). Because of the reasons listed above, I continued to implement writing

during math in my current placement, and I plan to make writing during math a priority in my future classroom.

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Appendix A

Codebook

Code Name	Level	Definition	Example
process of introducing writing into math	II	any mention or description of the process of introducing writing into math	“Today we are going to start something new in math. We are going to start writing in math.”
writing prompt	I	mention of introducing the writing prompt or the students talking about the writing prompt	I began reading the writing prompt. “Today we are going to respond to this prompt. Imagine one of your friends was absent...”
establishing procedures and expectations	I	when I describe or the students talk about the procedures or expectations for writing in math	“Each time we write, you will write in your math journals and you will respond to a prompt.”
showing examples	I	mention of me showing the students an example of a math journal entry or the students talk about my example	“Here’s an example I wrote...” I placed my writing under the iPad and read my writing to them.
additional prompting	I	giving students verbal prompts during writing in addition to the writing prompt	“If you are having trouble getting started, you may want to write an example number and talk about the place value of the digits.”
adjusting writing in math	I	making changes to the procedures and expectations of writing during math	Next time, I will have the vocabulary words typed write under the prompt so that all of the students can see it from their desks.
adjusting future instruction	I	mentioning or planning future instruction based on student’s math journal entries	Before the assessment tomorrow, I want to reiterate that specific part of our definition of equivalent fractions.
developing mathematical understandings	II	any description of students acknowledging their math understanding or of me understanding my students’ mathematical understandings	“Because you can understand it more. Like you write it and you can understand it more. What you think.”
purpose of writing	I	when a student or I describe or identify the	“When we write in math, we just want to take the time to

		purpose of writing in math	slow down and really think about what we know.”
accurate verbal response	I	students responding with accurate information verbally or describing talking during math	She replied, “fractions that are the same.”
accurate written response	I	describing students’ accurate responses in their math journal	Equivalent fractions are fractions that may look different but are equal to each other
including examples in writing	I	describing examples in writing or students mentioning the examples they used in writing	“So, they know how to do it and see how to do the steps and what I did with them.”
inaccurate written response	I	describing students’ inaccurate responses in their math journals	“Dividend is a times answer.”
remembering and understanding	I	students explaining how writing during math helps them remember or understand math concepts	“Because once you write, you can comprehend stuff way better.”
student attitudes and ideas	II	any mention or description of the students’ attitudes, opinions, or ideas about writing during math	“I don’t really have a non-favorite part. I like all about it.”
student confusion	I	describing situations when students show confusion about math concepts, expectations, or procedures through their verbal responses, written words, or actions	Students started asking what they were supposed to do and how to spell words.
avoiding writing	I	describing off task behaviors students display to avoid writing	He was looking around the room and playing with his glue stick inside his desk.
eagerness to write	I	describing student behaviors that show they are excited to write	He began writing before I finished talking. He wrote for four minutes without stopping.
“I don’t know what to write.”	I	students explaining that they don’t know what to write	“But I don’t know what to write”
“I’m done.”	I	students explaining that they are done writing	After about four minutes of writing, he put his pencil down and said, “I’m done.”
referencing	I	observing students looking	She looked up a couple times

prompting		back at the writing prompt	toward the writing prompt and vocabulary.
student confidence	I	students using language or behaviors that show their confidence in math	“There’s no hard part about writing in math.”
suggestions about changes	I	students making suggestions about changes in writing during math	“To have more time...like two more minutes.”
suggestions about keeping it the same	I	students making suggestions about keeping writing during math the same	“That we get to write and there’s quietness and there’s no yelling.”
good feelings	I	students describing good feelings towards writing during math	“That it’s fun and I really enjoy writing.”
bad feelings	I	students describing bad feelings towards writing during math	“Because writing during math is boring...just sitting there and just picking up a pencil and write, write, write.”

Appendix B

Student Survey Questions

1. Writing can help me show other what I know about math.
2. Writing during math can help me understand new math concepts.
3. Writing in math can help me think about what I understand about math.
4. Writing in math can help me think about what I do not understand about math.
5. It is important to write during math.
6. My teachers have asked me to write during math.
7. I want to write during math.
8. I write a lot during math.
9. It is easy to write during math.
10. I enjoy writing during math.
11. How do you feel about writing during math?
12. What will be the easiest part, for you, about writing during math? Why?

Appendix C

Student Survey Analysis

Survey Responses										
Name	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Howard	Green	Yellow	Green	Yellow	Yellow	Green	Yellow	Yellow	Yellow	Yellow
Claire	Yellow	Orange	Yellow	Red	Yellow	Yellow	Yellow	Orange	Yellow	Orange
David	Orange	Green	Green	Orange	Orange	Green	Red	Green	Green	Green
Steven	Yellow	Orange	Yellow	Red	Red	Red	Orange	Yellow	Orange	Orange
Martin	Green	Orange	Yellow	Green	Red	Red	Yellow	Red	Orange	Orange
Henry	Yellow	Yellow	Green	Orange	Orange	Yellow	Yellow	Orange	Orange	Green
Blake	Yellow	Green	Orange	Red	Yellow	Green	Orange	Orange	Yellow	Green
Natalie	Green	Green	Yellow	Green	Orange	Green	Yellow	Orange	Green	Green
Gabe	Green	Green	Green	Orange	Yellow	Yellow	Red	Orange	Yellow	Green
Jacob	Green	Orange	Orange	Yellow	Red	Red	Red	Red	Yellow	Red
Erica	Yellow	Green	Green	Red	Yellow	Orange	Orange	Yellow	Yellow	Green
James	Green	Orange	Green	Red	Yellow	Green	Red	Yellow	Green	Orange

Strongly Agree	Agree	Disagree	Strongly Disagree
Green	Yellow	Orange	Red

Percentages of Survey Responses				
Name	Strongly Agree	Agree	Disagree	Strongly Disagree
Howard	30	70	0	0
Claire	0	60	30	10
David	60	0	30	10
Steven	0	30	40	30
Martin	20	20	30	30
Henry	20	40	40	0
Blake	30	30	30	10
Natasha	60	20	20	0
Gabe	40	30	20	10
Jacob	10	20	20	50
Erica	30	40	20	10
James	40	20	20	20
student interviewed for positive perceptions			student interviewed for negative perceptions	

Appendix D

Writing Prompts

Week One, Day One

What are equivalent fractions? How do you know if fractions are equivalent? What questions do you still have about equivalent fractions?

Week One, Day Two

Imagine one of your friends was absent. He/She needs to know everything we've learned about equivalent fractions. How would you explain everything we've learned about equivalent fractions to your friend? What questions do you still have about equivalent fractions? Math words: equivalent, fractions, numerator, denominator

Week Two, Day One

Imagine one of your friends was absent today. He/She needs to know everything we've learned about place value. How would you explain place value to your friend? What questions do you still have about place value? Math words: hundred thousand, ten thousand, thousand, hundred, ten, one, place value, expanded form, expanded notation

Week Two, Day Two

Imagine one of your friends is have trouble remembering how to multiply. How would you explain the different strategies he/she could use to multiply? What questions do you still have about multiplication? Math words: array sketch, numeral, area model, distributive property, multiply

Week Three, Day One

Imagine one of your friends was absent. He/She needs to know how to solve word problems. How would you explain the steps to solving a word problem to your friend?

What questions do you still have about solving word problems? Math words: problem solving, understand the problem, plan, solve, evaluate

Week Three, Day Two

Imagine one of your friends is struggling to solve this word problem. Justin collected 57 cans for the local food bank. Alex collected 43 cans for the food bank. How many cans did Justin and Alex collect for the food bank? How would you explain to your friend how he/she could solve this problem? What questions do you still have about problem solving?

Week Four, Day One

Imagine one of your friends was absent. He/She needs to know all of the different parts to a division problem. How would you explain to your friend the three different parts to a division problem? What questions do you still have about division? Math words: dividend, divisor, quotient, divide, division

Week Four, Day Two

Imagine one of your friends asked you for help. He/She wanted to know how to solve a division problem and how to check his/her work. How would you explain to your friend how he/she could solve this division problem and how to could check his/her work? $18 \div 6 = \underline{\quad}$
What questions do you have about division? Math words: dividend, divisor, quotient, divide, division

Appendix E

Student Assessment Scores

Name	Score (percent correct)							
	Before Writing in Math				During Writing in Math			
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Howard	70	83	90	100	100	75	75	80
Claire	70	25	80	60	25	50	50	70
David	70	83	70	80	75	75	75	80
Steven	70	100	90	90	75	83	80	100
Martin	90	83	100	90	75	67	70	100
Henry	70	70	83	60	75	100	100	70
Blake	40	58	70	40	50	38	38	n/a
Natasha	70	83	90	60	75	75	75	80
Gabe	70	75	80	90	75	63	63	40
Jacob	70	75	80	70	75	75	75	80
Erica	80	83	70	70	13	17	20	100
James	90	80	100	100	88	92	88	90