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Mathematical Literacy: The Effects of Mathematics Journals on Student Understanding of Fractions in a Montessori Classroom

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Advisor _____ Date _____

It is a typical Monday morning. As students enter the classroom wearing brightly colored polo shirts embroidered with the school logo, their smiles are equally bright. This Title I public school in the heart of the city where 96% of the students qualify for free or reduced lunch has recently opened a Montessori option. Walking into the classroom, one 5th grade student eagerly asks, "Who's on the bread committee this week?" Baking bread is a weekly occurrence in the upper elementary (4th – 6th grade) Montessori classroom. During the first week of school, this same student vehemently threw materials to the floor declaring, "I HATE fractions!" In an effort to positively engage students in mathematics, the weekly bread-making tradition was implemented.

Through cooking, students experience the importance of fractions in everyday life. Each week, two students work together, read several recipes, select one, and submit a precise written list of needed ingredients. The next day, with the aid of a bread machine bought for $10 at the local thrift store, the students work together to follow directions, read fractions, measure ingredients, and bake bread. Once baked, students divide the bread into equal portions and serve. After several months of this routine, some recipes will need to be doubled or halved, and on it goes…

The bread committee provides a "hook" for some resistant students. It is also a practical application of the role of literacy in mathematics. The choice to focus on mathematical literacy and the effect of journaling on student understanding was influenced by research around mathematical vocabulary as well as the instructional practices of noted educators and researchers. The rigor of upper elementary math as defined in the common core requires students to not only perform calculations with accuracy, but to demonstrate strong reading comprehension through the interpretation of real-world word problems, and to articulate an understanding of

mathematical reasoning through clear and concise writing. Achieving grade level proficiency has practical life implications for students because research showed mathematical knowledge during elementary school as a strong predictor of financial stability in adulthood, and understanding fractions in fifth grade as a predictor of overall achievement in mathematics (Siegler & Lortie-Forgues, 2015).

Literature Review

An elementary understanding of mathematics has far-reaching, long-term implications. These implications are discussed in the 2015 Center for Poverty Research report and the research of Siegler and Lortie-Forgues (2015). Both studies indicated a strong correlation between poverty and level of education, specifically 5th grade mathematics (Siegler & Lortie-Forgues, 2015), supporting the premise that mathematical knowledge during elementary school is a strong predictor of financial stability in adulthood. Strengthening student growth and achievement in the elementary years supports the long-term goal of improving the quality of life for all students.

Understanding mathematical concepts is also important for students in the short term because they are assessed on standardized assessments that reflect Common Core State learning Standards. Research indicated one reason for low achievement on mathematics tests is the increase in the literacy expectations embedded in the assessments (National Council of Teachers of Mathematics [NCTM], 2000). The NCTM focused on the communication of mathematical reasoning where students were not only expected to complete mathematical computations, but to explain the reasoning behind strategies used to solve problems. Additionally, the 2010 adoption of the CCSS (Common Core State Standards) by many states completed what Bernadowski (2015) called a shift in focus requiring "an in-depth ability to make connections by using multiple models of solving, writing, and justifying answers" (p. 3). This shift in focus has led to

the increase in literacy expectations in mathematics assessments. This literature review examines current research in mathematical literacy, specifically mathematic vocabulary instruction, mathematical journaling for the upper elementary grades, and their impact on student understanding of fractions.

Mathematic Vocabulary Instruction

Most researchers agree that explicit vocabulary instruction is an essential piece in addressing low achievement on mathematics assessments. Blachowizc, Fisher, Ogle, and Watts-Taffe (2006) established vocabulary knowledge as a predictor of reading comprehension. In addition to this, Hughes, Powell, and Stevens (2016) wrote by the end of first grade, students must understand and apply 105 mathematics vocabulary terms and by the end of 5th grade, they are required to utilize 325. However, researchers differ in how they classify the needed vocabulary. Sifting through these differences and making sense of the various labels given to vocabulary can be an impediment when equipping classroom teachers with the tools needed to address this critical aspect of mathematics instruction. For clarity, the discussion of mathematical vocabulary instruction is divided into four parts: Classification of vocabulary, Vocabulary lesson planners, Precise teacher language, and Balanced approach.

Classification of vocabulary. Baumann and Graves (2010) summarized previous research explaining vocabulary is often classified into two groups, but researchers use different terms to identify these groups. Baumann and Graves used the terms domain-specific academic vocabulary and general academic vocabulary while Pierce and Fontaine (2009) used the terms technical and sub-technical. These are different terms but they contain similar groupings. Domain-specific vocabulary words or technical words are encountered within the context of a specific content area. For example, equilateral and isosceles belong to the specific content area

of geometry. In contrast, general academic vocabulary words or sub-technical words have a general meaning as well as a mathematical meaning. Words in this category include: product, difference, right, and table. This ambiguity of meaning confuses students, necessitating the need for explicit vocabulary instruction.

Vocabulary lesson planners. In addition to the differences in how vocabulary is classified, researchers also propose various lesson planners designed to better incorporate vocabulary into the mathematics lesson. For example, Smith and Angotti (2012) and Orosco (2014) proposed differing planning tools designed to scaffold vocabulary instruction within the mathematics lesson. Orosco's planning tool implemented a multifaceted word-problem solving strategy, known as Dynamic Strategic Math. This intervention utilized many of the same strategies found in literacy interventions such as vocabulary development, reading comprehension skills, questioning, and writing. However, these interventions were tailored to solve mathematical word problems. The results of Orosco's study showed that all participants improved in their problem-solving abilities.

Precise teacher language. In another vocabulary-focused study, Hughes, Powell, & Stevens (2016) changed the perspective from students' comprehensible input of mathematics vocabulary to teacher output. They looked at vocabulary from the perspective of teacher language, and the impact instructional vocabulary has on student understanding. They called attention to the negative impact that simplifying vocabulary in the primary years can have on students as they progress through the grades. This research highlighted the importance of using precise and accurate mathematical vocabulary during instruction. For example, they explained that teachers should say:

> *Let's sing our multiples of 4*, instead of saying, *Let's sing our skip-counting song for 4s*. Or, instead of saying, *Borrow the one from the four and put it next to the two to make twelve,* teachers should use place value vocabulary to say, *Exchange one ten for 10 ones, combine the 10 ones with the 2 ones to make twelve ones.* (Hughes et al., 2016, p. 11)

This practice may eliminate or lessen language confusion in later grades. Utilizing precise and accurate mathematical vocabulary may enable students to accurately describe mathematical strategies, increasing overall mathematical literacy.

A balanced approach. DiGisi and Fleming (2005), Kostos and Shin (2010), Pierce and Fountaine (2009), Nel (2012) and Orosco (2014) researched a balanced approach to mathematics instruction which included highly targeted vocabulary instruction as one part of the whole. While Bay-Williams and Livers (2009) advocated for balance in instruction to promote student learning in mathematics, like previously discussed researcher, they also divided words into two categories: context-related (everyday language) and mathematics-related (academic). They acknowledged that teachers must consider the vocabulary students will encounter. However, they stressed finding an appropriate balance between explicit vocabulary support and teaching based on rigorous mathematics content standards. Finding an appropriate balance depends on the demands of the lesson and the needs of the students. Researchers saw striving for an instructional balance as an essential piece of effective teaching.

Mathematical Journaling

Journaling is rooted in the Constructivist learning theory because it centers on student experiences (Krahenbuhl, 2016). With journaling, students take an active role in their own learning. Thus, journaling incorporates the Constructivist tenet of leveraging prior knowledge

and student experiences through the student actions of discourse, writing, and drawing representational models in their mathematics journals. This pedagogical approach of valuing student experience ties into culturally responsive pedagogy as discussed by Hammond (2015) as well as a pedagogy of liberation, presented by Watkins, better known by her pen name, bell hooks, in her 1994 book, *Teaching to Transgress: Education as the Practice of Freedom.* Placing value on all students' right to speak "is rooted in the assumption that we all bring to the classroom experiential knowledge…this knowledge can enhance our learning experience" (hooks, 1994, p. 84). Finally, Elkind's words help explain why journaling is indeed in accordance with Montessori teaching philosophy. Elkind (2003) writes:

> Montessori's constructivist leanings are reflected in her constant emphasis upon the child's own activity in his or her construction of knowledge and intelligence. 'The hands are the instruments of man's intelligence... He constructs his mind step by step till it becomes possessed by memory, the power to understand, the power to think.' (Montessori, 1967, p. 27)

In short, Montessori's emphasis on "the work of the hand" and how it connects to student mediation makes journaling a fitting choice for a Montessori classroom (Thompson, 2013). The intent for this action research was to observe the effect of student journaling on student understanding of fractions, and also on student ability to communicate that understanding both orally and in writing.

Journal writing within the mathematics content instruction supports student use of needed vocabulary (Tuttle, 2005). Burns' experience as an educator led to the practice of including writing as a regular part of mathematics instruction (2004). Burns found journaling beneficial to student learning because it required them to organize, monitor, and consider their thinking. She

used student writing for four purposes: keeping a chronological record of lessons received, writing out problem-solving strategies, explaining challenging math phrases and vocabulary, and writing about experiences during the learning processes of mathematics class. Finally, when she read her students' writing, she gained insight into their understanding which she could then use to plan differentiated instruction.

The 2010 study by Kostos and Shin went beyond unpacking mathematical vocabulary to include instructional time devoted to support student discussion. As part of their instruction, a variety of strategies needed to solve problems were modeled for the students, including how to explain (verbally and in writing) the problem-solving process in a systematic format, incorporate math vocabulary, draw models, and write equations. The results of their study showed this balanced approach led to improvement in students' use of mathematics vocabulary and their overall communication of mathematical thinking.

Focus on Fractions

This action research implemented an intervention utilizing mathematics journals to support students' ability to understand and communicate mathematical thinking. The choice to narrow the scope of this action research to the fourth, fifth, and sixth grade CCSS vertical progression in understanding, utilizing, and manipulating fractions was influenced by Siegler and Lorite-Forgues (2015) as they proposed understanding fractions in fifth grade as a predictor of overall achievement in mathematics. This action research was designed to unite the instructional practice of mathematical journal writing with the pedagogical influences found in Burns' *Lessons on Multiplying and Dividing Fractions* (2003) to answer the question: How will mathematics journaling and vocabulary instruction support student understanding of fractions?

As discussed previously, student journaling can support the instruction of fractions as it informs the teacher about what the student already knows (Burns, 2004). In this way, the teacher can build on prior knowledge and correct any misconceptions. In addition, the practice of verbalizing and modeling mathematical concepts helps to solidify student understanding (Burns, 2004). However, it is important to note that while this action research focused on journaling, it occurred in a Montessori classroom filled with concrete manipulatives. Manipulatives remained a central part of fractions instruction throughout the intervention. This is important to note because research suggests effective instruction must include the use of manipulatives (Naiser, Wright, & Capraro, 2004). The need to balance the use of manipulatives with a journaling intervention for this action research was apparent because, although students were comfortable using manipulatives to solve fraction problems, many were not able to transfer that understanding to drawing representational models on assessments, nor were they able to articulate their understanding in writing.

Conclusion

Although researchers and educators have tried to strengthen student understanding of elementary mathematics and solve low achievement on standardized math assessments for decades, there is a need for additional research. There are few studies on mathematics interventions or assistive instruction with English language learners (Doabler, Nelson, & Clarke, 2016; Orosco, 2014; Rutherford-Becker & Vanderwood; 2009). Also, Rutherford-Becker and Vanderwood (2009) write there are few studies on the relationships between mathematics and literacy assessments.

Methodology

Identifying the Design

This study used an intervention model. Throughout the intervention period, students wrote in their math journals during their math meeting. In addition, baseline, summative, and weekly progress monitoring assessments, which provide performance-based tasks, were given to show the progress made in the understanding of fractions. Finally, student conferencing and a teacher reflection journal were utilized. These additional qualitative tools were designed to gauge student and teacher perceptions of the effectiveness of the intervention in overall support of mathematical literacy, as well as student confidence in their understanding of fractions.

Defining the Setting and Subjects

The population for this action research were elementary school children ages 9-12 in an upper elementary classroom in a public Montessori school. Upper elementary includes grades 4th - 6th grade in one classroom. Mixed age grouping is part of normal educational practice in a Montessori classroom. This classroom was in a unique situation as a Montessori track was recently added as an educational option in this neighborhood school. Therefore, at the time of the intervention, the current class had only nine students: 2 fourth graders, 4 fifth graders, and 3 sixth graders. All students, grades 4th - 6th, participated in fraction-focused, math journaling lessons during the course of normal classroom instruction. All data was analyzed using grade-level standards, where applicable.

Describing Tools to Collect Data

Data was collected from grade level, district created, fraction-focused, pre and post-assessments (See Appendix B-E). Also, all students participated in fraction-focused, math journaling lessons based on the work of Marylin Burns during the course of normal classroom

instruction. At the end of each week in this six-week intervention cycle, teacher-created progress monitoring assessments measured the effectiveness of the lessons given (See Appendix H). Also, after week 3 and week 6, students participated in 1:1 student - teacher conferences. During the course of the conference, students rated their confidence on a 1-4 rubric in three areas: solving fraction problems, drawing models of fraction problems, and explaining their problem solving thinking in writing (See Appendix J). Finally, at the end of each week, the teacher/researcher responded to prompts in a reflective journal (See Appendix G).

Outlining the Procedure

Small group instruction and 1:1 student/teacher conferencing are natural parts of the Montessori educational practice. For this intervention, students met in a small group for 30 minutes, four days a week during the Montessori work period, and participated in fractions lessons that were grounded in the work of Marylin Burns. A foundational piece of this instruction included the statements about multiplication and division (See Appendix A), as well as the concrete Montessori fraction insets. Also, these lessons consistently included time for student talk. Students paired up to talk with each other, process their thinking, and practice the language of justification. When needed, after instruction, students were provided vocabulary cards to facilitate the use of academic language in their conversations. Students were instructed in active and reflective listening skills, as well as the English language structures used when paraphrasing and posing clarifying questions. They were provided with discussion guides to help them practice these skills, moving towards authentic, problem-solving discourse (See Appendix F). Then, students practiced drawing representational mathematic models to clarify and illustrate their thinking as they solve problems. Finally, with the use of a graphic organizers and sentence

frames, students explained their thinking in writing, justifying the strategy used to solve the problem (See Appendix K).

The teacher monitored student discussions, reviewed student journals and scored the journals using a rubric. The teacher also provided and scored weekly progress monitoring assessments (See Appendix I). She used this data, the data from the student conferences (See Appendix J), and teacher reflection journal (See Appendix G), to gauge the effectiveness of the intervention.

Description of Data Collected

Quantitative data was collected from grade level pre and post-assessments. The teacher-researcher scored the assessments using the learning progression rubric provided at the end of each grade-level assessment (See Appendix B-E). Each rubric included five levels, progressing from *Did Not Yet Meet Expectations*, to *Partially Met*, *Approached, Met Expectations* and *Exceeded Expectations*. With the exception of *Did Not Yet Meet*, the rubric provided detailed descriptors for meeting the requirements at each learning progression level. The pre-assessment was based in the standards from the previous year. For example, the fourth grade pre-assessment was similar to a third grade post-assessment. This enabled the researcher to determine student readiness to receive the current grade-level content. Also, both the math journals and the progress monitoring assessments were graded using a learning progression rubric, similar to the one used for the pre and post assessments (See Appendix I).

The final two pieces of data were qualitative. The first was the weekly teacher reflection journal which utilized reflective questioning to promote responsive teaching (See Appendix G). This professional practice facilitated the planning of any reteach necessary, and enabled the teacher to make changes in the presentation of future lessons, if needed. The final qualitative

piece was the student self-evaluation, with which the students rated their confidence on a four point rubric (See Appendix J). Students completed the self-evaluation in week three and week six of the intervention period. The researcher looked to see if there were correlations between student progress in understanding and student confidence. Since the researcher was also the teacher, she benefited from insights and observations that only an insider in the setting can acquire.

Data Analysis

Findings

The purpose of this action research project was to explore the impact of a small group intervention plan that focused on mathematical literacy, using student journals to effect understanding of fractions. This study used an intervention model that was rooted in the Constructivist learning theory, and was designed to strengthen vocabulary development, student discourse, mathematical modeling, and mathematical writing. The students were expected to speak, write, and draw their understanding of fractions, to use flexibility in solving various problems, and to utilize the language of justification when explaining their reasoning. The researcher observed the impact of this intervention model on student's ability to engage in the higher order thinking skills required from the common core.

The subjects for this study were school children ages 9-12 in an upper elementary classroom of a public Montessori school. Upper elementary includes 4^{th}-6^{th} grade in one classroom. Mixed age grouping is part of normal educational practice in a Montessori classroom. All students, grades 4^{th}-6^{th}, participated in the intervention during the course of normal classroom instruction. As seen in Table 1, a total of nine students participated in the intervention. There were two 4^{th} grade students, one male and one female, four 5^{th} grade

students, all of which were male, and three 6th grade students, two were male and one was female.

Table 1
Demographics

Grade Level	Male	Female
Fourth	1	1
Fifth	4	0
Sixth	2	1

Note: The school that has recently opened a Montessori option, resulting in the small class size.

Journaling as a Learning Tool for the Common Core

The first research question that this study addressed dealt with Mathematical Practice Standards as presented in the common core state standards for fourth through sixth grade, specifically CCSS 4.NF, 5.NF and 6.NS: *Will the use of student-created math journals in a Montessori upper elementary classroom improve student ability to makes sense of problems and persevere in solving them, reason abstractly and quantitatively, construct viable arguments, and critique the reasoning of others when assessed on understanding fractions?* To answer this question the teacher researcher gave a pre- and post-assessment. The pre-assessment was based on the previous grade's content in the area of fractions. For example, the fifth grade students were tested on their understanding of fourth grade fraction content. In the same way, the sixth grade students' pre-assessment tested their understanding of 5th grade fraction knowledge. These pre-assessments determined the students' preparedness level to learn their current grade-level content. Then, at the end of the intervention period, the students were given a post-assessment which tested their understanding of fractions at their current grade level as defined in the common core.

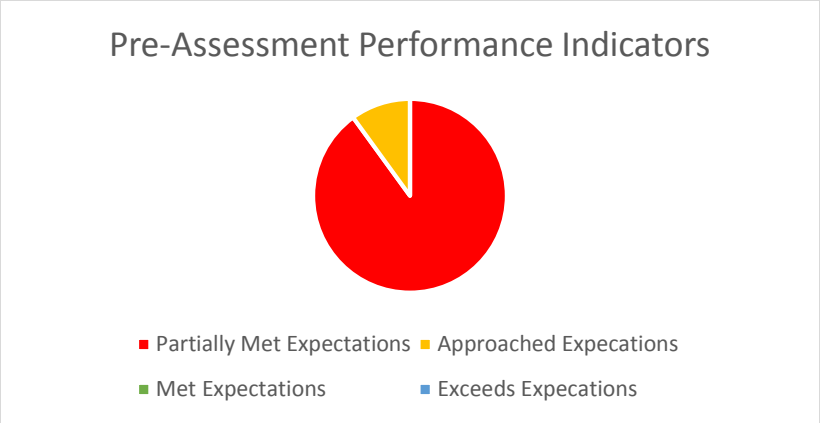

Figure 1. Students' pre-assessment scores. This shows students' preparedness levels to receive grade level content.

According to Figure 1, not one of the students in this study began the school year adequately prepared to learn the fraction content for their grade level. While one student would be considered *underprepared* for the current grade level content, most students would be considered *significantly underprepared.*

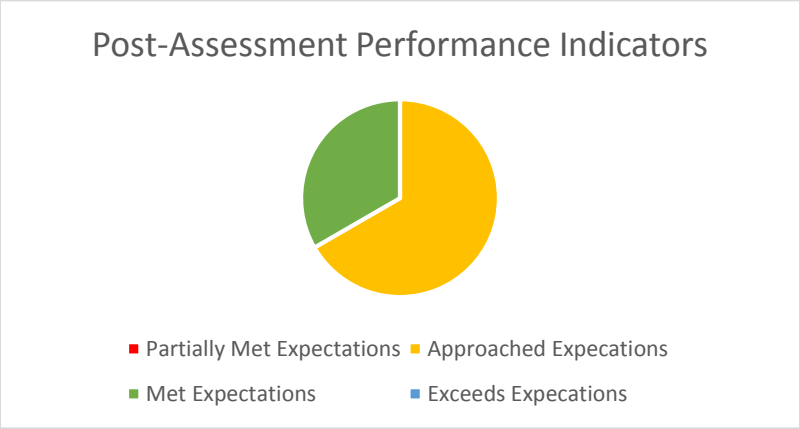

Figure 2. Students' post-assessment scores. This shows students' expectation levels in understanding current grade level content.

After the intervention period, a post assessment was given. As seen in Figure 2, a majority of students fell into the *approaching expectations* category.

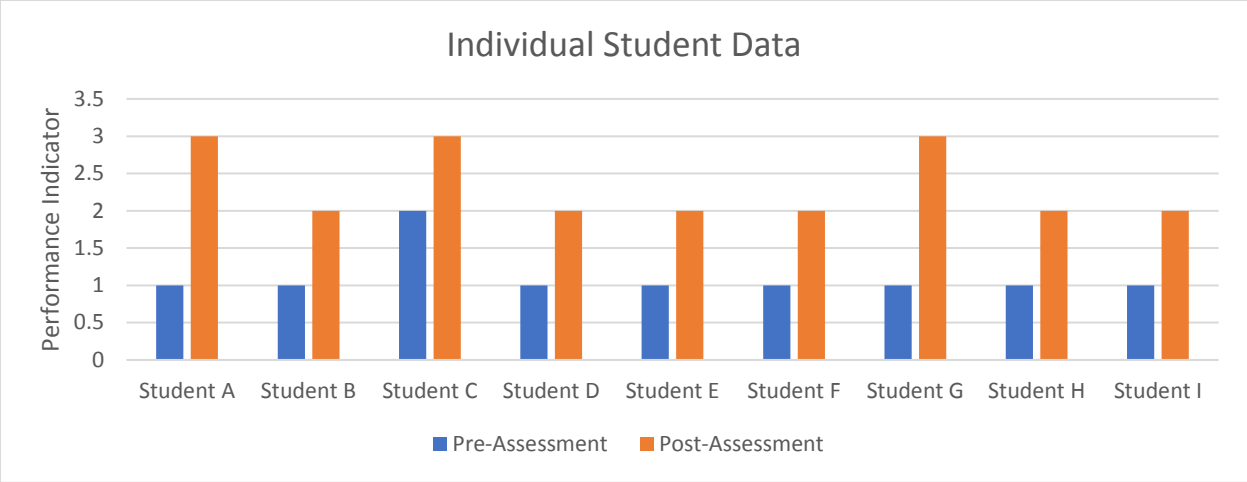

Figure 3. Individual pre and post-assessment data. A performance indicator of 3 means *met expectations* for grade-level understanding.

Figure 3 provides a more detailed view as it compares each student's pre and post side by side on the bar graph. As indicated in Figure 3, three students were able to demonstrate grade level understanding of fractions on the post assessment. Also, most students made more than a year's growth in their ability to demonstrate grade level understanding. It is important to consider that the pre-assessment contained material from the previous grade level and the post assessment contained material from the current grade level. Since the content of the assessments increased in difficulty, to make one year's growth, the student would remain at the same performance indicator level. Therefore, it can be reasoned that to move from *partially met expectations* on a 4th grade level assessment to *approached expectations* on a fifth grade level assessment required at least a year and a half of growth.

Journaling as a Communication Tool

It may be helpful to think of the second and third research questions as components of the first question. The second question was: *To what extent will math journals effect student communication of mathematical concepts involved in understanding fractions*? This teacher-researcher wanted to explore the relationship between student confidence and student

communication. To answer this question, both the student journals and the student self-perception evaluations were analyzed. The self-perception evaluations measured student confidence levels. The premise being, a confident student (even if that confidence is unwarranted) will more readily engage in authentic discussion around mathematical concepts. In addition, the teacher-researcher made anecdotal notes in her weekly journal around student discourse. All these factors influenced lessons for the coming week, including if a reteach was needed.

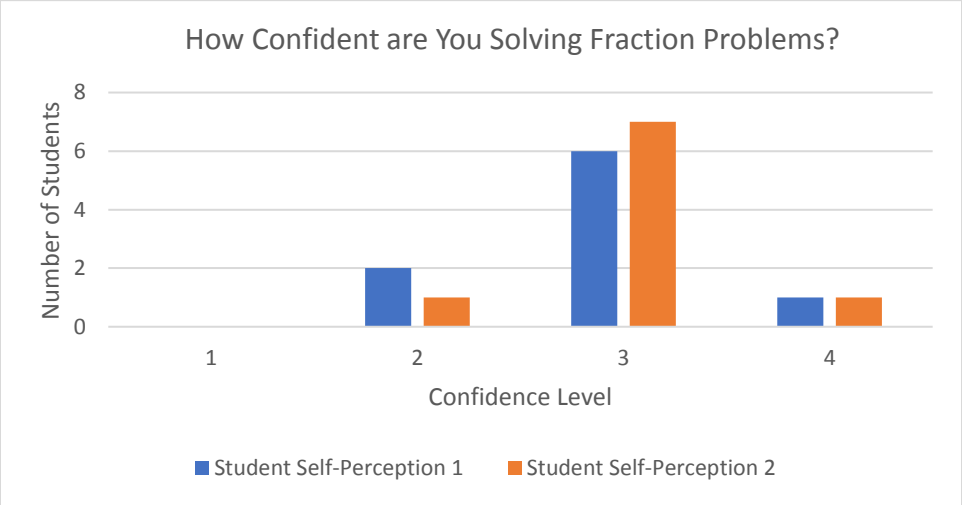

Figure 4. Student self-evaluation - Confidence in solving fraction problems. There was minimal notable growth in this area.

Figure 4 shows a relatively high confidence level for solving fraction problems with minimal growth. This is interesting considering not one of the students in this study began the school year adequately prepared to learn the fraction content for their grade level. It may be that the high emphasis on the use of fraction manipulatives in the Montessori classroom led to this high confidence level for solving fraction problems. The self-perception quiz did not indicate if the fraction problems would be solved concretely or abstractly. Upon reflection, a more effective question may have been, *How confident are you in solving fraction problems without materials?* This researcher considers representational drawings to be a necessary bridge between

concrete understanding (using the Montessori fraction insets) and the abstract understanding (solving fraction equations). As the intervention progressed, students experienced the different methods of solving: with materials, with representational drawings, using abstract calculations. It may be that this increase in exposure, moving from concrete, to representational, and then to abstraction, resulted in what looks like minimal growth in confidence.

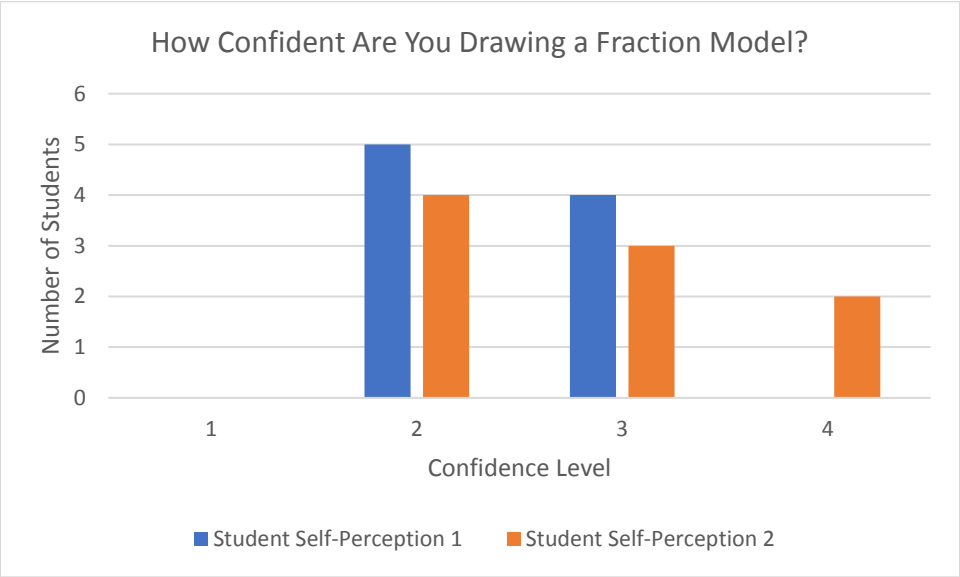

Figure 5. Student self-evaluation - Confidence in drawing a fraction model. A 2 confidence level means somewhat confident and a 4 means extremely confident.

Figure 5 shows confidence in drawing mathematical models to be an area of student growth for some students, with two students ending the intervention feeling extremely confident in their ability to solve by drawing fraction models, while four other students ended feeling only somewhat confident. Drawing models is a complex task and may require more than the time allotted in the intervention window to show growth for all students.

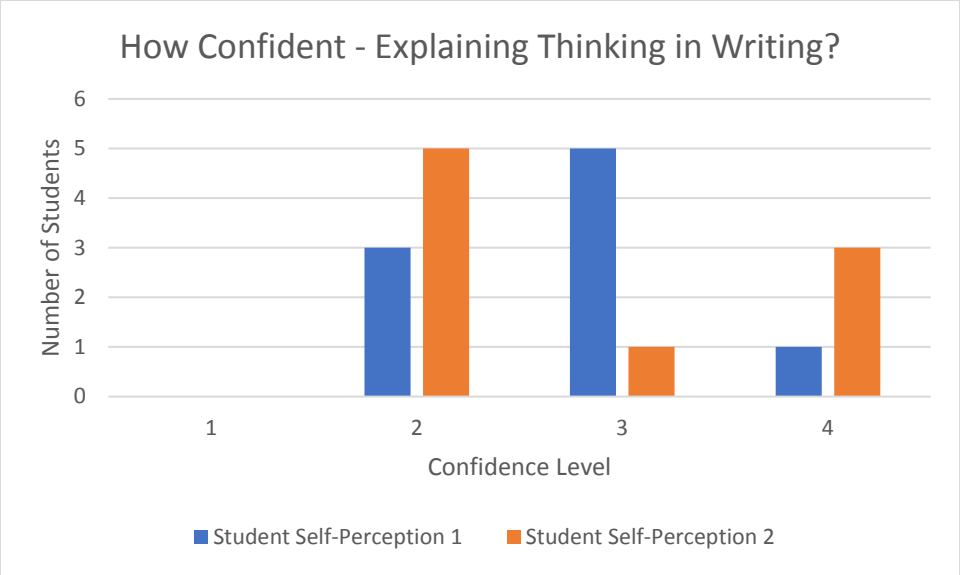

Figure 6. Student self-evaluation - Confidence in explaining thinking in writing. This graph shows negative growth.

Figure 6 shows some students less confident about their writing at the end of the intervention period than they were in the middle of the intervention period. This makes sense when considering that four students were only somewhat confident in drawing models at the end of the intervention. Writing, using the language of justification, is a synthesis of student understanding. Many students began this intervention with very little understanding of what it means to justify their reasoning. It is the teacher observer's opinion that the confidence levels may actually indicate a deeper understanding by students of what this means. *The more you know, the more you realize how much you don't know.*

Drawing Mathematical Models

The third question addressed the conceptual understanding of multiplying and dividing fractions: *What effect will math journals have on student ability to draw models representing their understanding of fractions?* Many of the weekly progress monitoring assessments given as a part of the intervention plan required students to draw representational models and to write about their problem solving process, using the language of justification. These assessments,

graded on a rubric included in Appendix I *Scoring Rubric for Weekly Constructed Response and Journals*, were used to show the depth of student understanding. Conceptual understanding of fractions can be measured not merely by correct answers, but by analyzing the students' representational models. The level of thinking required to complete the calculations needed to solve a fraction multiplication problem is not complex: multiply numerator by numerator, denominator by denominator, then simplify if needed. This shows that correct calculation does not require conceptual understanding. However, drawing a visual model representing an equation in which a fraction is multiplied by another fraction, and justifying how that particular equation applies to a word problem, demonstrates the depth of conceptual understanding.

Table 2

Scoring of Weekly Progress Monitoring Assessments

Student	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
A	2	3	3	2	2	3
B	1	2	2	3	2	3
C	1	3	3	2	3	2
D	1	3	3	2	2	3
E	1	3	3	3	2	2
F	2	3	3	2	3	2
G	1	3	2	2	2	2
H	2	3	2	2	3	3
I	1	2	2	2	2	2

Note: Students were scored on a 5 point rubric (See Appendix I).

As seen in Table 2, students struggled with the first assessment; six students were not even able to make an attempt to answer the prompt. This speaks to the challenge of the Common Core Mathematical Practice Standard 1: Make sense of problems and persevere in solving them. All students began to show improvement in week two. Not all students were able to demonstrate on the assessment a complete understanding of the week's lesson, but all students made an attempt. This shows growth in Mathematical Practice Standard 1. Some students needed prompting and some needed to use the fraction insets to solve the problem before attempting to

solve with models and calculations, but all students persevered in solving. The performance indicators on the rubric (Appendix I) detail the levels of support the students used to solve the problem. A quick glance through the progress monitoring assessments shows the rigor increased slightly from week to week. Some students maintained a steady 2 each week. Since the progress monitoring assessments increased in rigor, a steady score still indicates some growth. One student score decreased from a 3 to a 2 on the last assessment. This provided the teacher and student with the opportunity to reteach challenging concepts. The reteaching opportunities provided by the data from the progress monitoring assessments strongly prepared students for the post assessment.

According to the data outlined above, the small group intervention utilizing mathematical journals was shown to have a positive effect on student understanding of fractions. All students made at least a year and half growth, and three students were able score a *met expectations* on the post assessment. In the end, all students showed growth in both their understanding of fractions, and in their ability to make sense of problems and persevere in solving them.

Action Plan

The purpose of this action research project was to explore the impact of a small group intervention plan that focused on mathematical literacy, and the effect of student journals on student understanding of fractions. This study used an intervention model that was rooted in the Constructivist learning theory and was designed to strengthen vocabulary development, student discourse, mathematical drawing, and mathematical writing.

As the intervention progressed, three benchmarks of understanding emerged:

- **Speak it:** Collaborative student discussions to organize thinking and practice language skills.

- **Draw it**: Students draw models to illustrate calculations and demonstrate an understanding of the process.
- **Write it.** Students write about the process using the language of justification.

These benchmarks are not in a sequential order. For some students, verbal processing was the entry-point of understanding. However, some students needed to draw before they could speak their understanding. Also, one particularly reserved student preferred to write his understanding first, then draw, then speak. Finally, since the data from the pre-assessments showed all students entering below grade level (See Figure 1), with a variety of strengths and challenges, the small group nature of the intervention was a practical and necessary component.

There were several unforeseen challenges as well as unexpected benefits experienced during this intervention project. Near the start of this study, it became apparent that mathematical literacy is a more complex area of inquiry than the teacher-researcher first understood. Interpreting grade level understanding of fractions, as described by the Common Core State Standards is complex, and interpreting three grade levels, which exist in any Montessori classroom, adds even more complexity. However, the three grade levels contributed to a deeper understanding of the vertical alignment within the fraction-focused standards. An improvement may have been to focus on only one area of mathematical literacy: vocabulary development, student discourse, or mathematical writing. However, the body of research showed that focusing on literacy skills in isolation had limited benefits. DiGisi and Fleming (2005), Kostos and Shin (2010), Pierce and Fountaine (2009), Nel (2012) and Orosco (2014) researched a balanced approach to mathematics instruction which included highly targeted vocabulary instruction as one part of the whole. Since vocabulary development, student discourse, and mathematical

modeling and writing are interdependent skills; it may not have been helpful or possible to support them in isolation.

The professional reflection provided by the weekly teacher journal (See Appendix F) was not sufficient for the amount of re-teaching needed; the teacher-researcher often made daily alterations to lesson plans. Also, as the project progressed, the Marilyn Burns lessons were not sufficient to lead the students to the level of understanding required by the anticipated post-assessment. For example, the initially planned weekly constructed responses were not at the same level of complexity as those on the assessment. Therefore, additional progress monitoring assessments were created, and some of the originals were not used. However, Burns' descriptions of how to draw representational models for fraction multiplication and division proved useful and provided a needed bridge between the concrete Montessori fraction materials and the abstract standard algorithms.

The practical logistics associated with this intervention also proved challenging. Not only was content changed throughout the project, the schedule was also disrupted. The fidelity of the six week focus was not kept, and the plan for six weeks of lessons actually took nine weeks to implement. Mandatory district assessments given during the intervention period contributed to this schedule disruption, as preparation for the district assessments impacted the time available for the fraction focused interventions. Also, a teacher strike occurred during the intervention period. Although the strike lasted only three days, several students did not return to school until the next week. Also, there were three snow days called during the intervention period, further interrupting the instruction schedule.

The use of a math journal proved to be a useful tool. Students (and teacher) were able to quickly reference notes when needed. For example, students stapled Marilyn Burns' six true

statements about multiplication and ten statements about division to the inside cover of each notebook (See Appendix A). The students discussed and proved each statement in the context of whole numbers before applying them to fractions. Students then wrote the proofs in their journals. Students often used their journal when solving math problems during the Montessori work period. Also, this ready record of student progress in writing and drawing models contributed to the responsive nature of the lesson planning during the intervention. This affirmed Burn's conclusion, "By reading their journals you can evaluate their progress and recognize their strengths and needs" (2001, 17). An improvement would be to use notebooks with grid lines or graph paper.

Including discussion in each lesson required more explicit instruction than was initially anticipated. Students used the discussion guides (See Appendix F) throughout the intervention. Also, for particular lessons, specific sentence stems or vocabulary cards were provided as an aid. This instructional move was patterned after the research of Bauman and Graves (2010) and Pierce and Fontaine (2009) who differentiated between words encountered in general conversation and those encountered within the context of a specific content area. The stems and cards seemed to take away from the authentic nature of the discussions because students often paused to reference the guides. However, their use did support student facility with academic language and sentence structure. With additional practice, students may use the reference guides less.

Based on the pre and post assessments, as well as the weekly constructed responses, and individual student journals, the overall result of this intervention plan was an increase in student understanding. As supported by the 2009 research of Walshaw and Anthony on the teacher's role in student discourse, incorporating a balance of student conversation and teacher talk

resulted in effective instruction. As supported by the research of Kostos and Shin (2010), since math journals support students within a broad range of understanding and ability, math journals work well in a multi-aged Montessori classroom. Additional instruction in the area of mathematical literacy can begin with the utilization of small group instruction, student discourse, and student-generated mathematical journals.

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Appendix A

Six Statements about Multiplication

1. Multiplication is the same as repeated addition when you add the same number again and again.

2. *Times* means "groups of".

3. A multiplication problem can be shown as a rectangle.

4. You can reverse the order of the factors and the product stays the same.

5. You can break numbers apart to make multiplying easier.

6. When you multiply two numbers, the product is larger than the factors unless one of the factors is:

- zero or
- one or
- a fraction smaller than one.

Ten Statements about Division

1. You can solve a division problem by subtracting.

2. To divide two numbers, $a \div b$, you can think, "How many *b*s are in *a*?" (Except when dividing by zero)

3. You can check a division problem by multiplying.

4. The division sign (÷) means "into groups of".

5. The quotient tells "how many groups" there are.

6. You can break the dividend apart to make dividing easier.

7. Remainders can be represented as whole numbers or fractions.

8. If you divide a number by itself, the answer is one.

9. If you divide a number by one, the answer is the number itself.

10. If you reverse the order of the dividend and the divisor, the quotient will be different, unless the dividend and divisor are the same number.

Appendix B

Grade 4 Pre Assessment

School Garden

Directions: Please complete all questions directly on your handout. You may use any tools or materials you normally use to complete this task. When you have completed this task, please raise your hand for directions.

The four 3rd grade classes at Jefferson Elementary School are planting a garden.

Part A
Dividing up the Garden

1) Using the space below, show how each class can have an equal section of the garden.

2) What fraction of the garden will each class plant?

Class A

Class B

Class C

Class D

Grade 4 Pre Assessment Continued…

Part B

Planting the Garden

1) On Monday and Tuesday, Class A and Class B each planted seeds in their sections of the garden. Show how much of the garden was used.

Write the fraction of the garden that was used: _____

2) On Wednesday, Class C planted tulips in their section of the garden.

After the tulips were planted, how much of the garden is **left** for planting? _____

3) On Thursday, Class D planted carrots in their section of the garden.

What **fraction** of the garden is now planted? _____

Grade 4 Pre Assessment Continued…

Part C

Planting Seeds on the Number Line

The students are preparing to plant seeds in the garden. They are using number lines to plant them an even distance apart. Help them figure out the missing fractions.

1) Number Line 1

On the number line below, label the blanks with the correct missing fractions.

2) Number Line 2

Below is a number line. Label these fractions on the number line: $\frac{2}{8}, \frac{5}{8}, \frac{1}{2}, \frac{6}{8}$

3) Number Line 3

On the number line below, label the number line by following the directions.

- Label the fraction that is equivalent to $\frac{6}{8}$
- Label the fraction that is equivalent to $\frac{2}{8}$

Grade 4 Pre Assessment, Continued…

Part D

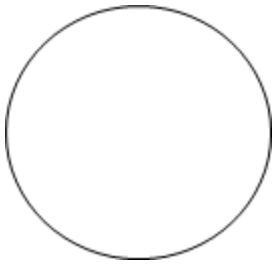
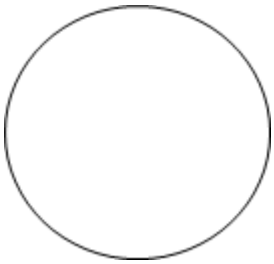
Dividing Watermelons

Jake and Melvin each picked a watermelon from the garden that were the same size. Jake cut his into three equal pieces and Melvin cut his into eight equal pieces.

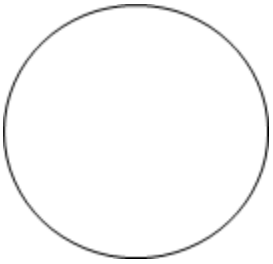
1) Who has the watermelon with the bigger pieces? _____

How do you know? In the space below, draw or write how you know.

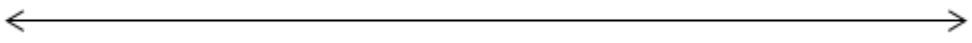
2)

Jake ate $\frac{2}{3}$ of a watermelon. Shade in the amount Jake ate.  Jake's Watermelon	Melvin ate $\frac{7}{8}$ of a watermelon. Shade in the amount Melvin ate.  Melvin's Watermelon

3) Suzie picked a watermelon the same size as Jake's watermelon. She cut her watermelon in six equal pieces. She wants to eat an amount equal to what Jake ate. Shade in the fraction that Suzie wants to eat of the watermelon.



4) Use the number line to show that Suzie's fraction and Jake's fraction are equivalent.



Grade 4 Pre Assessment, Continued…

	Scoring Rubric				
	Exceeded Expectations	**Met Expectations**	**Approached Expectations**	**Partially Met Expectations**	
Part A	In addition to the attributes of Met Expectations, **Part D #4**: students correctly partition the number line between 0 and 1 into equal sections and include fractions as labels. Correctly represent 2/3 as equivalent to 4/6 .	Students: 1. Accurately partition the shape into 4 equal sections. 2. Correctly identify each section as 1/4 .	Students: 1. Partition the shape into 4 sections, but the sections are not equal. 2. Incorrectly identify the fraction for one or more sections.	Students: 1. Partitions do not represent 4 sections. 2. Incorrectly identify the fraction for one or more sections or fractions are missing.	**No score**
Part B		Students: 1. Accurately partition the shape to represent half of the garden used and correctly identify the section as 1/2 or 2/4 . 2. Correctly identify 1/4 of the garden is left for planting. 3. Correctly identify 4/4 as planted.	Students: 1. Accurately partition the shape to represent half of the garden, but incorrectly identify the fraction. 2. Indicate how much of the garden has been planted (e.g., ¾) 3. Incorrectly identify what fraction of the garden is planted or provide an answer not in fractional form.	Students: 1. Partition the shape such that is does not represent half of the garden. 2. Provide an incorrect quantity to indicate how much of the garden is left for planting or response is missing. 3. No response.	
Part C		Students: 1. Correctly label the number line with the missing fractions: 2/6, 3/6, 4/6, 6/6, or 1.	Students: 1. Label the number line with minor errors. 2. Label number line with minor	Students: 1. Incorrectly label the number line (e.g., fraction written in between	

		2. Correctly label the number line with the given fractions:2/8, 5/8, 1/2, 6/8 located directly above or below the mark. 3. Correctly label the number line with fractions: 1/4 and 3/4 located directly above or below the mark.	errors (e.g., fraction order is correct, but error in labeling correct mark on number line). 3. Provide the correct equivalent fraction for only one fraction or provide both equivalent fractions, but mislabel the marks on the number line.	marks, incorrect labeling). 2. Incorrectly label the number line (e.g., fraction written in between marks, incorrect labeling). 3. Provide incorrect equivalent fractions or provide an incomplete or missing response.	
Part D		Students: 1. Correctly indicate that Jake's watermelon was cut into bigger pieces and provide clear and accurate justification for response. 2. Provide accurate representation of thirds and eighths. 3. Accurately partition the shape into 6 equal sections and shade in 4 of the 6 sections.	Students: 1. Correctly indicate that Jake's watermelon was cut into bigger pieces, but justification is not clear or reasonable. 2. Show shapes divided into three parts and eight parts, but divisions are not equal. 3. Show shape divided into sixths, but divisions are not equal. Correctly shade in 4 of the 6 sections.	Students: 1. Do not indicate that Jake's watermelon was cut into bigger pieces. Explanation is not reasonable or is missing. 2. Do not accurately show thirds and/or eighths. 3. Provide inaccurate representation of sixths and/or do not shade in 4 sections.	

Appendix C

Grade 4 Post Assessment (AND Grade 5 Pre Assessment)

Fractions and Food!

Directions: Please complete all questions directly on your handout. You may use any tools or materials you normally use to complete this task. When you have completed this task, please raise your hand for directions.

Part A

Lily and Anna are making chocolate chip cookies. They will need $4\frac{1}{4}$ cups of chocolate chips to make cookies for their friends. Lily has $2\frac{3}{4}$ cups of chocolate chips. Anna has $1\frac{3}{4}$ cups of chocolate chips.

1) If they combine their chocolate chips, how much will they have? *Explain or show how you know.*

2) Will they have enough chocolate chips to make the cookies for their friends? *Explain how you know and include a number sentence in your explanation which includes <, =, or >.*

Grade 4 Post Assessment (Grade 5 Pre), Continued…

Part B

1) Lily uses $\frac{2}{5}$ of a bag of nuts. Complete the diagram below to show how many tenths Anna must use so that she uses the same amount of nuts as Lily.

$$\frac{2}{5} = \frac{\quad}{10}$$

Will Lily use more than $\frac{1}{2}$ of a bag of nuts? *Explain your thinking. Include a visual fraction model to illustrate your response.*

Part C

Anna had a bag of candy. She took $\frac{2}{6}$ of the bag for herself and then shared some candy with Lily. Lily took $\frac{3}{6}$ of the candy that was originally in the bag. How much of the bag of candy is left? *Explain your thinking and include a visual fraction model to illustrate the fractions. Provide an equation.*

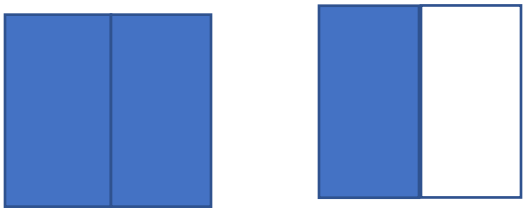
Grade 4 Post Assessment (Grade 5 Pre), Continued…

Part D

Read the thinking of Lily and Anna for the problem below.

1 brownie

What part is shaded for the brownies below?



Lily: I think $\frac{3}{4}$ is shaded.

1) Explain Lily's thinking. Is Lily correct? Why or why not?

Anna: I think that $\frac{3}{2}$ are shaded.

2) Explain Anna's thinking. Is Anna correct? Why or why not?

Grade 4 Post Assessment (Grade 5 Pre), Continued…

Scoring Rubric				
Performance Indicators	**Exceeded Expectations**	**Met Expectations**	**Approached Expectations**	**Partially Met Expectations**
Part A	In addition to the attributes of Met Expectations, Students: **Part D:** Correctly interpret and critique the validity of Lily and Anna's thinking and provide evidence of reasoning to support both answers. [Lily is interpreting the diagram to be ¾ of the two brownies is shaded. Anna is thinking that each brownie is cut in half and 3 of the halves are shaded.]	Students:) Accurately solve problem using the properties of operations and provide a clear and accurate justification for their reasoning. 2 3/4 + 1 3/4 = 4 2/4or 4 1/2]) Accurately compare fractions and indicate they will have enough chocolate chips to make the cookies. Provide a clear and accurate justification for their reasoning including a number sentence with the correct symbol to represent the problem.	Students: 1) Reason through problem using properties of operations, but make calculation error(s); or provide correct response, but do not explain solution. 2) Accurately compare fractions, but do not provide a clear explanation and/or do not provide an accurate number sentence or number sentence is missing.	Students: 1. Provide limited or missing evidence of reasoning and make calculation error(s). 2. Incorrectly compare fractions. 3. Provide explanation that is not reasonable or is missing.
Part B		Students: 1) Accurately compare fractions by creating the equivalent fraction 4/10 . 2) Accurately compare 4/10to 1/2 . Provide a clear and reasonable justification for their reasoning and accurately use a visual fraction model to illustrate their response.	Students: 1) Make calculation error when creating the equivalent fraction. 2) Accurately compare the fractions and use a visual fraction model to illustrate the comparison, but do not provide a justification.	Students: 1. Provide an answer that is not reasonable or is missing. 2. Incorrectly compare the fractions and/or justification is not reasonable.

Part C		Students: 1. Accurately solve the problem and provide a clear and reasonable justification including a visual fraction model and equation. [1/6]	Students: 1. Reason through problem, but make calculation error(s); or provide a correct response but do not explain solution.	Students: 1. Provide limited or missing evidence of reasoning and make calculation error(s).
Part D		Students: 1. Correctly determine that Lily is incorrect and Anna is correct. 2. Student reasoning supports one of their answers, but is missing from the other.	Students: 1. Correctly determine that Lily is incorrect and Anna is correct. 2. Provide limited evidence of reasoning to support their answers.	Students: 1. Correctly state that either Lily is incorrect or that Anna is correct. 2. Provide limited evidence of reasoning to support their answers.

Appendix D

Grade 5 Post Assessment (AND Grade 6 Pre Assessment)

Roberto's Cats

Directions: Please complete all questions directly on your handout. You may use any tools or materials you normally use to complete this task. When you have completed this task, please raise your hand for directions.

Roberto has 3 cats: Sammy, Tommy, and Suzi

Part A

1) Roberto feeds his cats Cat Crunchies.
Each day Sammy eats $\frac{1}{2}$ of the box, Tommy eats $\frac{1}{8}$ of the box, and Suzi eats $\frac{1}{4}$ of the box.
What fraction of the whole box do the cats eat, in all, each day?
Explain your thinking. Include a visual fraction model and equation to represent the problem.

2) Sammy weights $15\frac{3}{4}$ pounds. Tommy weighs $7\frac{1}{4}$ pounds. Suzi weighs $8\frac{3}{8}$ pounds.
Roberto believes that Tommy and Suzi's combined weight is more than Sammy's weight. Is Roberto correct? *Explain your reasoning. Include a visual fraction model to justify your reasoning.*

3) How much heavier is Sammy than Suzi? *Show your reasoning.*

Grade 5 Post Assessment (AND Grade 6 Pre Assessment), Continued…

Part B

1) Roberto's cats spend much of the day sleeping.
Tommy sleeps for $\frac{3}{5}$ of the day and Suzi sleeps for $\frac{7}{10}$ of the day.

Which of the two cats sleeps longer?
How much longer does this cat sleep each day?
Explain your thinking.

2) Sammy sleeps for $\frac{1}{6}$ of the day in the morning and $\frac{1}{4}$ of the day in the afternoon. Roberto estimates that Sammy sleeps less than half of the day. Is his estimation reasonable?

Without calculating, *explain your thinking* using number sense of fractions or *benchmark fractions.* **Reminder**: Benchmark fractions are the common fractions we can picture in our minds or easily draw. For example: $\frac{1}{2}$ and $\frac{1}{4}$ are benchmark fractions.

Grade 5 Post Assessment (AND Grade 6 Pre Assessment), Continued…

Part C

1) Roberto's cats often share a carton of milk.
The cats drink $\frac{4}{5}$ of a carton of milk each day.
If Roberto buys 5 cartons a week, will he have enough milk for the cats?
Explain your thinking. Include a visual fraction model and equation to represent the problem.

2) One day, Sammy drank $\frac{2}{5}$ of a carton of milk. Tommy drank $\frac{3}{4}$ times as much as Sammy. How much of the carton of milk did Tommy drink? *Include a visual fraction model and equation to represent the problem.*

Grade 5 Post Assessment (AND Grade 6 Pre Assessment), Continued…

3) Using Roberto's cats, create a story context for $3 \times \frac{5}{8}$ and interpret the product.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

Grade 5 Post Assessment (AND Grade 6 Pre Assessment, Continued…

Scoring Rubric				
Performance Indicators	**Exceeded Expectations**	**Met Expectations**	**Approached Expectations**	**Partially Met Expectations**
Part A	In addition to the attributes of Met Expectations, **Part C #3:** students create an accurate story context using information embedded in Roberto's Cats PBT and interpret the product.	Students: 1. Accurately solve problem and provide a clear and accurate explanation including a visual model and equation to represent the problem. ½ + ⅛ + ¼ = 7/8 2. Correctly solve problem and provide a clear and accurate justification for their reasoning including a visual fraction model. [Roberto is not correct.] 3. Correctly indicate how much heavier Sammy is than Suzi and provide clear and accurate justification for their reasoning. [7 3/8 pounds heavier]	Students: 1) Correctly solve problem, but do not provide a clear or accurate explanation, visual model or equation to represent the problem. 2) Correctly indicate that Roberto is not correct, but justification is not clear, reasonable, or is missing. Correctly interpret situation, but make calculation error.	Students: Make calculation error and provide an inaccurate explanation for solution.) Provide incorrect response and explanation is not reasonable or missing.) Provide limited or missing evidence of reasoning and make calculation error.
Part B		Students: 1. Correctly solve problem indicating that Suzi sleeps longer by 1/10 of a day and provide a clear and accurate explanation of their thinking. 2. Provide clear and accurate justification for their	Students: 1) Correctly indicate that Suzi sleeps longer, but incorrectly indicate how much longer Suzi sleeps or explanation is not clear,	Students:) Provide limited or missing evidence or reasoning. 2) Provide limited or missing evidence of reasoning.

		reasoning using number sense of fractions or benchmark fractions. [Roberto's estimate is reasonable.]	reasonable, or is missing. 2) Correctly indicate that Roberto's estimate is reasonable, but explanation does not rely on number sense of fractions or benchmark fractions.	
Part C		Students: 1. Correctly solve problem indicating that Roberto will not have enough milk. Provide accurate visual fraction model and equation to represent the problem. [No, she would need more than 5 cartons.] 2. Correctly solve problem and provide clear and accurate justification to explain thinking. Provide accurate visual fraction model and equation to represent the problem. [6/20 of a carton] 3. See Exceeds Expectations Column	Students: 1) Correctly indicate that Roberto will not have enough milk, but do not provide a clear or accurate explanation, visual model or equation to represent the problem. 2) Correctly solve problem, but do not provide a clear or accurate explanation, visual model or equation to represent the problem.	Students:) Make calculation error and provide inaccurate explanation for solution. 2) Make calculation error and provide inaccurate explanation, visual model or equation to represent the problem.

Appendix E

Grade 6 Post Assessment

Mowing the Lawn for Soccer

Directions: Please complete all questions directly on your handout. Answer each question completely and be sure to show all work. When you have completed this task, please raise your hand for directions.

Part A. The lot next to Michael's house is empty. He want to use it to play soccer with his friends, so he is going to cut the grass.

1. Michael's lawn mower requires $\frac{1}{3}$ of a gallon of gas to cut grass for one hour. He has $\frac{5}{6}$ of a gallon of gas in a gas can. How long can Michael cut the grass with this amount of gas?

Show how you found your answer.

2. How wide is the rectangular lot if it has a length of 100 feet and an area of 7905 square feet? Show your work.

3. How long will it take Michael to cut the lot if he can cut 2550 square feet per hour? Show your work?

4. Does Michael have enough gas in his can to cut the lot? Justify your response.

Grade 6 Post Assessment, Continued…

Part B

Low Temperatures for January 2, 2014, through January 10, 2014

	Jan. 2	Jan. 3	Jan. 4	Jan. 5	Jan. 6	Jan. 7	Jan. 8	Jan. 9	Jan. 10
New York, NY	27˚ F	11 ˚ F	10 ˚ F	26 ˚ F	37 ˚ F	6 ˚ F	10 ˚ F	21 ˚ F	30 ˚ F
Erie, PA	14 ˚ F	16 ˚ F	16 ˚ F	33 ˚ F	-2 ˚ F	-10 ˚ F	-10 ˚ F	4 ˚ F	26 ˚ F
Detroit, MI	12 ˚ F	0 ˚ F	0 ˚ F	14 ˚ F	-5 ˚ F	-12 ˚ F	-12 ˚ F	-3 ˚ F	21 ˚ F
Fargo, ND	-25 ˚ F	-25 ˚ F	-7 ˚ F	-19 ˚ F	-24 ˚ F	-24 ˚ F	-21 ˚ F	-9 ˚ F	-21 ˚ F

Use the table of temperature above to complete the following.

1. Jerry said that one day the low temperature for his hometown, Detroit, Michigan, was 12 degrees below zero. On which day could this temperature have occurred?

2. Plot the temperatures for January 8 on the number line below. Name the two cities that had opposite temperature on this day.

←-----|-------|-------|-------|-------|-------|-------|-------|-------|------|--------|-------|------|-------|--------|--------|-------|-------|-----→

3. Alicia, who lives in Fargo, North Dakota, wrote the inequality -7 ˚ F > -19 ˚ F to compare the temperatures on January 4 and January 5. Explain what this comparison means about the temperature for these two dates.

4. On January 10, Rayshon noticed that the low temperature for the city he lives in had an absolute value of 21. In which city could Rayshon live? Explain your reasoning in terms of temperature.

Appendix F – Conversation and Collaboration Guides

Academic Conversation Guide

Asking for Evidence

Why do you think that?

What makes you think that?

Clarifying

Can you tell me more about that?

What do you mean?

I have a question about that…

Agreeing / Affirming

I agree with ___ that ___.

I had similar thinking. I also think that _____.

That is interesting because _____.

Disagreeing and Challenging

I disagree with you because.…

I have a different idea. I think…

A different way of looking at this is…

That's a good point, however…

Academic Collaboration Guide

Roles

Person 1: Asks the question.

Person 2: Answers the question.

Person 1: Paraphrases – "I heard you say that…"

Person 3:

- Asks for evidence
- Asks clarifying questions
- Agrees or disagrees

Person 2: Responds

Everyone – goes to the evidence in the text or problem.

Continue until there is agreement that the question has been answered FULLY and CORRECTLY**.**

Everyone: make any changes in their notes as needed

Appendix G

Weekly Teacher Observation Journal Prompts

The teacher will respond to these six prompts each week of the intervention:

1. What was the instructional focus this week? What did students need to know prior to this lesson in order to be successful?
2. What were the essential academic vocabulary words?
3. What actions did you take to make the needed academic language accessible to all learners? (Think: visuals, chants/songs/gestures, background knowledge, cultural responsiveness)
4. Using a 4 point scale (4 highest – 1 lowest), how would you rate students' overall enthusiasm for using math journals?
5. If the enthusiasm is low, how can you increase engagement?
6. Based on the end of week progress monitoring assessment, does anything require a reteach? Additional practice with scaffolds? Additional time for independent practice?

Appendix H, Weekly Constructed Responses for Grade 4, Grade 5, & Grade 6

Week 1

Plotting Fractions and Mixed Numbers on a Number Line

Plot each fraction or mixed number on a number line, clearly indicating which two whole number it falls between.

1. $\frac{1}{4}$ <--->

2. $\frac{3}{5}$ <--->

3. $1\frac{2}{3}$ <--->

4. $6\frac{2}{8}$ <--->

Appendix H

$\frac{4}{5}$ is greater than $\frac{1}{2}$. Is this true or false? Show your reasoning by drawing a model. Explain your reasoning by writing the steps you took to solve.

Appendix H

Week 1 Continued…

Halfway Between

Anna wrote:

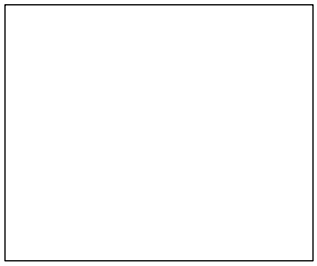
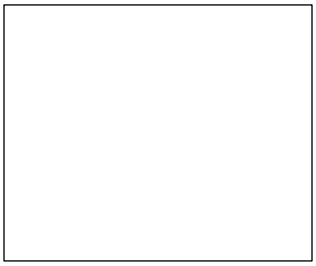
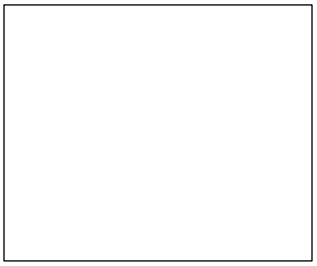
$\frac{1}{5}$ *is halfway between* $\frac{1}{4}$ *and* $\frac{1}{6}$ *because 5 is exactly in between 4 and 6.*

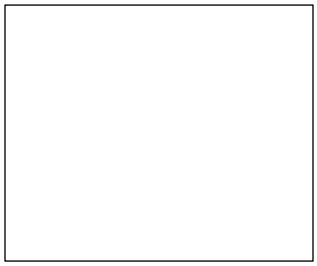
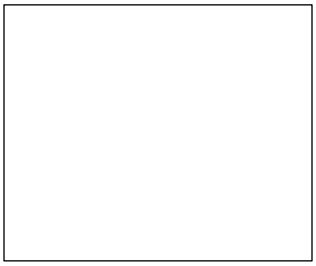
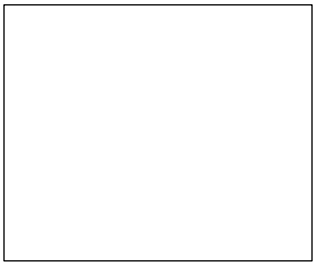
Is Anna correct or incorrect? Explain your reasoning.

Appendix H

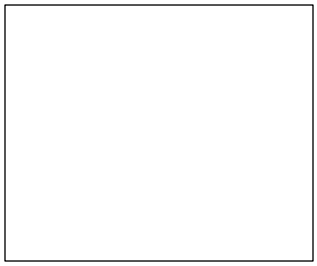
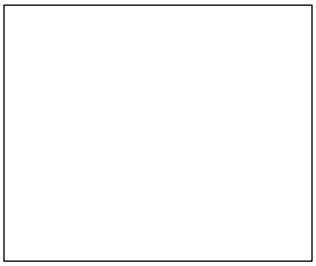
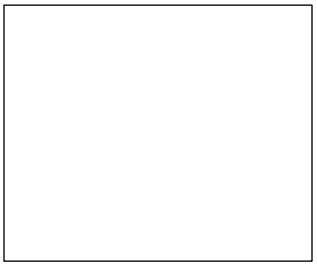
Week 2 Grade 4. Solve, using fraction models.

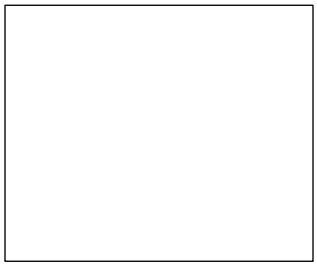
$\frac{1}{6} + \frac{3}{6} =$ $\frac{2}{3} + \frac{1}{3} =$ $\frac{1}{8} + \frac{5}{8} =$

$\frac{1}{4} + \frac{3}{6} =$ $\frac{2}{3} + \frac{1}{6} =$ $\frac{1}{5} + \frac{5}{10} =$

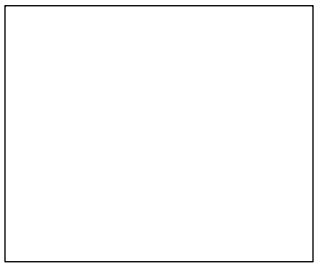






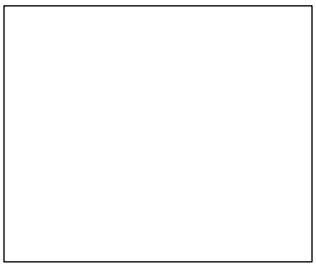
Appendix H

Week 2 Grades 5 & 6 Multiplying with Rectangles: For each problem, show how you can find the answer by dividing the square.

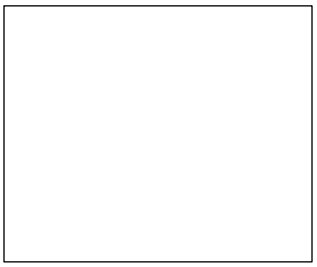
$\frac{1}{2}$ X $\frac{1}{3}$ =



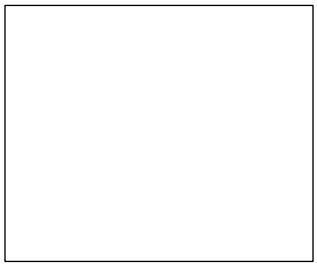
$\frac{1}{2}$ X $\frac{2}{3}$ =



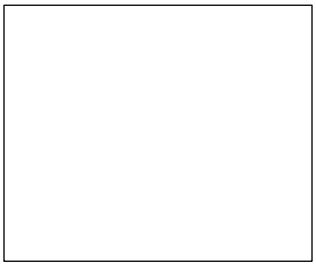
$\frac{1}{2}$ X $\frac{5}{8}$ =



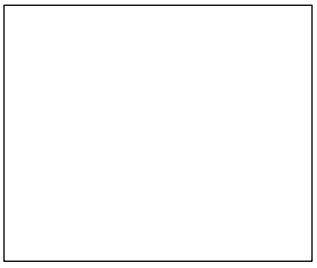
$\frac{1}{3}$ X $\frac{1}{3}$ =



$\frac{1}{3}$ X $\frac{2}{3}$ =



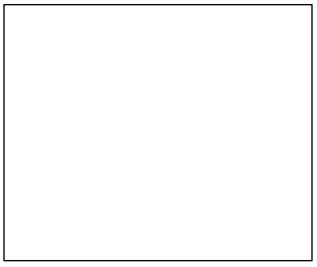
$\frac{1}{3}$ X $\frac{5}{8}$ =



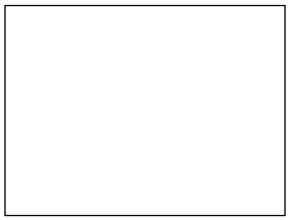
$\frac{3}{4}$ X $\frac{1}{3}$ =

$\frac{3}{4}$ X $\frac{2}{3}$ =

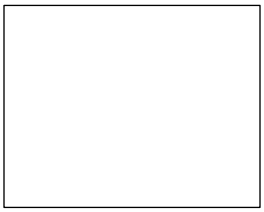
$\frac{1}{3}$ X $\frac{5}{8}$ =



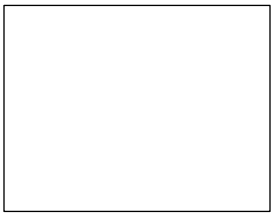
$\frac{2}{3}$ x $\frac{1}{3}$ =



$\frac{2}{3}$ x $\frac{2}{3}$ =



$\frac{2}{3}$ x $\frac{5}{8}$ =



Appendix H

Grades 5 & 6 , Continued…

B. Multiplying with and without Rectangles, Version 1.

Solve each problem in two ways, numerically and by drawing a rectangle.

You will receive square grid paper for your drawings.

1. $2\frac{1}{2}$ x 5
2. $\frac{1}{3}$ x 4
3. $1\frac{1}{2}$ x $1\frac{1}{2}$
4. 4 x $1\frac{1}{3}$
5. $1\frac{1}{4}$ x $2\frac{1}{2}$

Appendix H

Appendix H

Grades 5 & 6 , Continued. Multiplying with and without Rectangles, Version 2.

Solve each problem in two ways, numerically and by drawing a rectangle. You will sketch your own rectangles for each problem.

1. $3 \times 3\frac{1}{3}$

2. $3 \times 2\frac{1}{4}$

3. $1\frac{1}{2} \times 1\frac{3}{4}$

Appendix H

Week 3 – Grade 4

Estimation and Exact Fraction Addition and Subtraction

Solve the problems using both estimation and calculation.

Estimate	Exact
$\frac{3}{4} + \frac{1}{4} =$ <---------->	$\frac{3}{4} + \frac{1}{4} =$
$\frac{1}{3} + \frac{2}{6} =$ <---------->	$\frac{1}{3} + \frac{2}{6} =$
$\frac{3}{4} - \frac{2}{4} =$ <---------->	$\frac{3}{4} - \frac{2}{4} =$

Appendix H

Week 3 – Grades 5 & 6

Estimation and Exact Fraction Multiplication

Solve the problems using both estimation and multiplication.

Estimate	Exact
$\frac{3}{4}$ x $2\frac{2}{5}$ = <----------> <---------->	$\frac{3}{4}$ x $2\frac{2}{5}$ =
$\frac{1}{3}$ x $4\frac{2}{5}$ = <----------> <---------->	$\frac{1}{3}$ x $4\frac{2}{5}$ =
$3\frac{3}{4}$ X $5\frac{2}{3}$ = <----------> <---------->	$3\frac{3}{4}$ X $5\frac{2}{3}$ =

Appendix H

Grades 5 & 6, Continued…

Explain Your Reasoning

Solve each problem in two ways, numerically and by drawing a rectangle. You will sketch your own rectangles for each problem.

Use the *Explain Your Reasoning* sheet.

1. $4\frac{1}{3}$ x 7

2. $5\frac{5}{6}$ x $\frac{1}{2}$

Appendix H

Show and Explain Your Reasoning!

Show your reasoning mathematically by drawing a model.

Explain your reasoning by writing the steps you took to solve.

In order to solve the problem, first I _____

_____

_____

Next, I _____

_____

_____

Finally, I _____

_____

_____

The solution to the problem is _____

Appendix H

Week 4 – Apply the 10 Statements about Division to Solve. Either solve the problem in two different ways **OR** solve in one way and check your answer by multiplying. Use the 10 statements about division as a resource.

$5 \div \frac{1}{2} =$

$3 \div 1\frac{1}{2} =$

$1 \div \frac{1}{2} =$

$1 \div \frac{1}{3} =$

$6 \div \frac{3}{4} =$

$3 \div \frac{3}{4} =$

Week 4 Continued…

Grade 4: Only use first 3 problems [+, -, x]. **Grades 5 & 6**: Use all.

Problems with $\frac{3}{4}$ and $\frac{1}{4}$

On the next sheet solve the problems and explain why each answer makes sense.

$\frac{3}{4} + \frac{1}{4}$

$\frac{3}{4} - \frac{1}{4}$

$\frac{3}{4} \times \frac{1}{4}$

$\frac{3}{4} \div \frac{1}{4}$

$\frac{1}{4} \div \frac{3}{4}$

Appendix H

Week 4, Continued… Problems with $\frac{3}{4}$ and $\frac{1}{4}$

Solve the problems and explain why each answer makes sense.

$\frac{3}{4} + \frac{1}{4}$

In order to solve the problem, I _____
_____.
Next, I _____.
The solution to the problem is _____.
I know this because _____
_____.

$\frac{3}{4} - \frac{1}{4}$

In order to solve the problem, I _____
_____.
Next, I _____.
The solution to the problem is _____.
I know this because _____
_____.

Appendix H

$\frac{3}{4}$ X $\frac{1}{4}$

In order to solve the problem, I _____
_____.
Next, I _____.
The solution to the problem is _____.
I know this because _____
_____.

$\frac{3}{4}$ ÷ $\frac{1}{4}$

In order to solve the problem, I _____
_____.
Next, I _____.
The solution to the problem is _____.
I know this because _____
_____.

$\frac{1}{4} \div \frac{3}{4}$

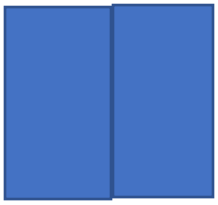
In order to solve the problem, I _____
_____.
Next, I _____.
The solution to the problem is _____.
I know this because _____
_____.

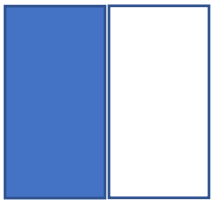
Appendix H

Week 5 –Grade 4

 = 1 cake

Joe thinks $\frac{3}{4}$ is shaded. Anna thinks $\frac{3}{2}$ is shaded.





Who is correct and why? Please explain.

_____

_____

_____

_____

_____

_____

_____

Appendix H

Week 5 –Grade 5

Using the tale of the *Three Little Pigs*, create a story context for $3 \times \frac{2}{3}$ and interpret the product.

Once upon a time there were three little pigs. Their names were Joey, Julio, and Jamal. These little pigs were growing up, and they were always hungry! Their momma baked their favorite dessert, peanut butter cream pie with extra whipped cream. Momma gave them each $\frac{2}{3}$ of a pie to eat! What a treat! How many pies did Momma bake?

$3 \times \frac{2}{3} = \frac{6}{3} = 2$ Therefore, Momma baked 2 pies for the three little pigs.

Your turn! Using the four boys of 5^{th} grade, create a story context for $4 \times \frac{3}{7}$ and interpret the product.

_____
_____
_____
_____
_____
_____
_____
_____
_____

Appendix H

Week 5 - Grade 6

A lot near Garden Place Academy is empty. The 6th graders want to turn it into a garden and use it to grow vegetables. To do this they need to till the soil. ("To till the soil" means to break up the dirt so it is loose and ready for planting)

1. Mrs. Bechler has a gas powered rototiller. This is a machine (like a lawn mower) that has sharp discs that move quickly to break up the soil into small pieces. Mrs. Bechler's rototiller requires $\frac{1}{4}$ of a gallon of gas to till the soil for one hour. She has $\frac{5}{8}$ of a gallon of gas in a gas can. If the 6th grade students borrow Mrs. Bechler's rototiller and gas can, how long can they till the soil with this amount of gas? Show how you found your answer.

2. How wide is the rectangular lot if it has a length of 1000 feet and an area of 84,355 square feet? Show your work.

3. How long will it take the sixth grade students to till the lot if they can till 16,871 ft. per hour? Show your work.

4. Do they have enough gas in the can to till the lot? Justify your answer.

Appendix H

Week 5 Grade 6, Continued.

Extra Credit:

1. Rewrite $\frac{345}{3450}$ as a division problem.

2. Solve the division problem. Show your work.
   Hint: You will find it helpful to use a decimal strategy.

Week 5 – Grade 5 & 6 Extra Practice

Five Problems

Choose any two numbers and use them for five problems – addition, subtraction, multiplication, and two division problems. At least one number must be a fraction or mixed number. Explain your answers.

Appendix H

Week 6 – Grade 4

Fabian and Lindzi are making bread for the classroom. They will need $4\frac{3}{8}$ cups of flour for the recipe. Mrs. Bechler has $1\frac{5}{8}$ cups of flour in the cabinet. She was able to borrow $2\frac{7}{8}$ cups of flour from the cafeteria.

1. If they combine the flour, how much will they have? Explain or show how you know.

2. Will they have enough flour to make the bread for the classroom? Explain how you know and include a number sentence in your explanation which includes < , = , or >.

Appendix H

Week 6 – Grade 5

There are three boys in the Santos family, Julio, Andre, and Tyrel. They drink $\frac{3}{5}$ of a carton of orange juice EVERY day!
If Mrs. Santos buys 5 cartons a week, will she have enough orange juice for her sons?
Explain your thinking. Include a visual fraction model and equation to represent the problem.

2) One day, Julio Santos drank $\frac{1}{4}$ of a carton of orange juice. Tyrel Santos drank $\frac{2}{3}$ times as much as Julio. How much of the carton of orange juice did Tyrel drink? *Include a visual fraction model and equation to represent the problem.*

Appendix H

Week 6 – Grade 6 (Rational Numbers)

Low Temperatures for January 2, 2014, through January 10, 2014

	Jan. 2	Jan. 3	Jan. 4	Jan. 5	Jan. 6	Jan. 7	Jan. 8	Jan. 9	Jan. 10
Albany, NY	7˚ F	11 ˚ F	8 ˚ F	34 ˚ F	34 ˚ F	9 ˚ F	2˚ F	32 ˚ F	31 ˚ F
Lancaster, PA	23 ˚ F	16 ˚ F	16 ˚ F	35˚ F	-9 ˚ F	-4 ˚ F	7 ˚ F	4 ˚ F	32 ˚ F
Flint, MI	12 ˚ F	0 ˚ F	0 ˚ F	14 ˚ F	-5 ˚ F	-5˚ F	-2 ˚ F	-8 ˚ F	21 ˚ F
Boise, ID	-25 ˚ F	-25 ˚ F	-5 ˚ F	-14 ˚ F	-24 ˚ F	-24 ˚ F	-21 ˚ F	-9 ˚ F	-21 ˚ F

Use the table of temperature above to complete the following.

1. Jerry said that one day the low temperature for his hometown, Fint, Michigan, was 5 degrees below zero. On which day could this temperature have occurred?

2. Plot the temperatures for January 8 on the number line below. Name the two cities that had opposite temperature on this day.

←-----|-------|-------|------|--------|-------|-------|-------|-------|-------|--------|-------|-------|-------|-------|-------|-------|-------|-----→

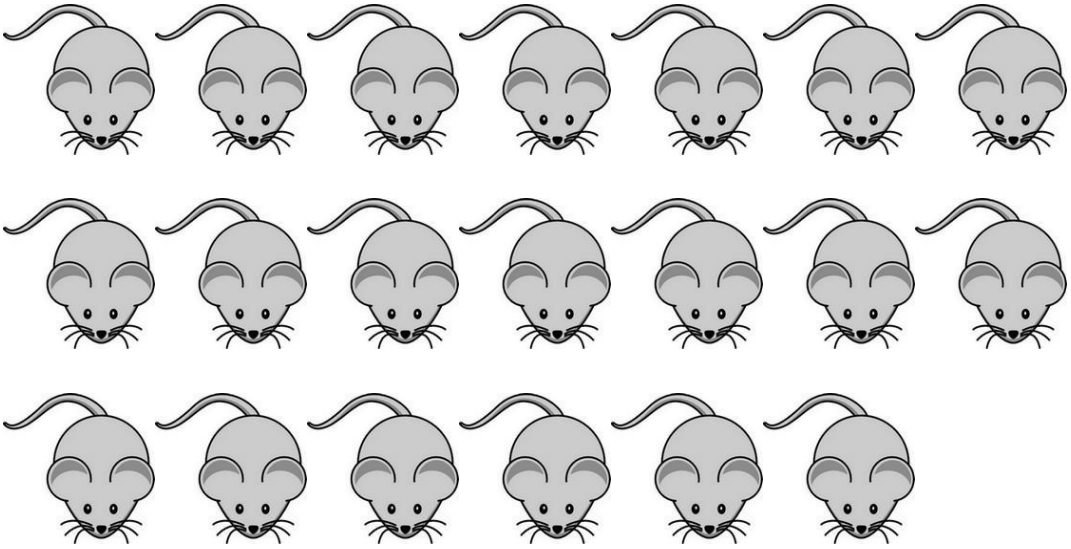
3. Mark, who lives in Boise, Idaho, wrote the inequality -5 ˚ F > -14 ˚ F to compare the temperatures on January 4 and January 5. Explain what this comparison means about the temperature for these two dates.

4. On January 5, Bruce noticed that the low temperature for the city he lives in had an absolute value of 14. In which city could Bruce live? Explain your reasoning in terms of temperature.

Appendix H

Week 6 - Grades 5 & 6. An Experiment with Mice

For an experiment with 20 mice, $\frac{3}{5}$ got vitamins with their food. How many mice got vitamins? Explain your thinking.



Appendix I Scoring Rubric for Weekly Constructed Response and Journals

Performance Indicators	Weekly Progress Monitoring Learning Progression Rubric				Did Not Yet Meet
	Exceeded Expectations	**Met Expectations *(Performance Indicators)***	**Approached Expectations**	**Partially Met Expectations**	
	Students add, subtract, multiply or divide fractions and multiply whole numbers by fractions and use visual fraction models to represent the problem.	Students add, subtract, multiply or divide fractions by fractions and multiply whole numbers by fractions **and** use visual fraction models to represent the problems.	Students add, subtract, multiply or divide fractions by fractions and whole numbers by fractions **using visual fraction models to represent the problems.**	Students add, subtract, multiply or divide fractions by fractions and whole numbers by fractions **with support (e.g., teacher questioning, models).**	
	Students solve word problems involving multiplication of fractions and mixed numbers using visual fraction models and equations. Students construct a well-organized oral and written justification of their solution **and critique the validity of other's solutions.**	Students solve word problems involving multiplication of fractions **and mixed numbers** using visual fraction models **and equations** to represent the problem**. Students construct a well-organized oral and written justification of their solution.**	Students solve word problems involving multiplication of fractions **using visual fraction models to represent the problem.** Students use scaffolds (e.g., sentence frames) to explain their solutions orally and in writing.	Students solve word problems involving multiplication of fractions **using scaffolds and supports (e.g., manipulatives, teacher questioning, models).** Students use scaffolds (e.g., sentence frames) to explain their solutions orally and in writing.	

Appendix J

Student Self-Perception Survey and Rubric

How confident are you solving fraction problems?

4	3	2	1
I am extremely confident. I know that I can always solve fraction problems!	I am confident. I can usually solve fraction problems.	I am somewhat confident. Sometimes I have difficulty solving some fraction problems.	Oh no! I am so lost. I have no idea how to solve fraction problems.

How confident are you drawing a fraction model and using it to solve fraction problems?

4	3	2	1
I am extremely confident. I know that I can always draw fraction models and use them to solve fraction problems.	I am confident. I can usually draw fraction models and use them to solve fraction problems.	I am somewhat confident. Sometimes I have difficulty drawing fraction models and use them to solve fraction problems.	Oh no! I am so lost. I have no idea how to draw fraction models and use them to solve fraction problems.

How confident are you in explaining your thinking in writing?

4	3	2	1
I am extremely confident! I know that I can always explain my thinking orally and in writing when solving fraction problems.	I am confident. I can usually explain my thinking orally and in writing when solving fraction problems.	I am somewhat confident. Sometimes I have difficulty explaining my thinking orally and in writing when solving fraction problems.	Oh no! I am so lost. I have no idea how to explain my thinking orally and in writing when solving fraction problems.

Appendix K

Show. Explain and Justify Your Reasoning!

Show your reasoning mathematically by drawing a model.

Explain your reasoning and justify your answer.

In order to solve the problem, first I _____

_____

Next, I noticed _____, so I _____

_____

Finally, I _____

_____.

The solution to the problem is _____. I know this because_____

_____

_____

_____.

Appendix L – Parent Permission Form, English & Spanish

Utilizing Mathematics Journals to Deepen Student Understanding of Fractions
Parental Permission Form

November 26, 2018

Dear Parents/Guardians,

In addition to being your child's Montessori Upper Elementary teacher, I am a St. Catherine University student pursuing a Masters of Education in Advanced Montessori Studies. As a capstone to my program, I need to complete an Action Research project. I am going to study the effect of mathematics journaling on students' understanding of fractions because many students are unable to show grade-level understanding of fractions on our assessments, and I have learned that journaling can be an effective tool in teaching students how to show and explain their understanding of mathematical concepts.

In the coming weeks, I will be introducing mathematics journaling and incorporating some of the lessons of Marilyn Burns, a nationally known mathematics educator, in our Montessori mathematics lessons. We will continue to use our Montessori materials. However, the need for the journaling intervention is apparent because although all students are comfortable using the Montessori manipulatives to solve fraction problems, many are not able to transfer that understanding to the drawing of representational models on assessments. Nor are they able to articulate their understanding of fractions in writing.

All students will participate as members of the class. In order to understand the outcomes, I plan to analyze the data obtained from the results of our lessons and assessments. It is my hope that by using mathematics journals, which focus on the practice of drawing fractions and fraction models and writing out the specific steps needed to solve fraction problems, I will deepen your child's understanding of fractions. All strategies implemented, and assessments given are part of our normal educational practice.

The purpose of this letter is to notify you of this research and to allow you the opportunity to exclude your child's data (pre- and post-assessments, weekly formative assessments, math journals, and student/teacher conferences) from my study.

> **If you decide you want your child's data to be in my study**, you don't need to do anything at this point.
>
> **If you decide you do NOT want your child's data included in my study**, please note that on this form and return it by December 10, 2018. Note that your child will still participate in these lessons, but his/her data will not be included in my analysis.

In order to make an informed decision, please note the following:

- I am working with a faculty member at St Kate's and a project coach to complete this particular project.

- The purpose of this project is to strengthen your student's understanding of fractions and his/her ability to communicate that understanding both orally and in writing. There are no foreseeable risks to participation in this project.

- I will be writing about the results that I get from this research. However, none of the writing that I do will include the name of this school, the names of any students, or any references that would make it possible to identify outcomes connected to a particular student. Other people will not know if your child is in my study.

- The final report of my study will be electronically available online at St Catherine University library. The goal of sharing my research study is to help other teachers who are also trying to improve their teaching.

- There is no penalty for not having your child's data involved in the study; I will simply delete his or her responses from my data set. Your decision of whether or not to allow use of your child's data will have no impact on your relationship with the Garden Place Academy or with me.

If you have any questions, please feel free to contact me. You may ask questions now, or if you have any questions later, you can ask me, or my project coach, Alisha Brandon, Ajbrandon@stkate.edu, who will be happy to answer them. If you have questions or concerns regarding the study and would like to talk to someone other than the researcher, you may also contact Dr. John Schmitt, Chair of the St. Catherine University Institutional Review Board, at (651) 690-7739.

You may keep a copy of this form for your records.

_____ _____

Eileen Bechler Date

OPT OUT: Parents/Guardians, in order to exclude your child's data from the study, please sign and return by December 10, 2018.

I do NOT want my child's data to be included in this study.

_____ _____

Signature of Parent/Guardian Date

Utilizando diarios de matemáticas para profundizar la comprensión de las fracciones por parte de los estudiantes

Formulario de autorización de los padres

26 de noviembre, 2018

Queridos Padres/Guardianes

Además de ser la maestra de Montessori de Primaria Superior de su hijo/a, soy un estudiante de la Universidad de St. Catherine que cursa una Maestría en Educación en estudios avanzados de Montessori. Como mi proyecto final, necesito completar un Proyecto de Investigación en Acción. Voy a estudiar el efecto que tiene un diario de matemáticas en la comprensión de Fracciones. Muchos estudiantes no demuestran comprensión de fracciones en su nivel de grado en nuestras evaluaciones, y he aprendido que el diario puede ser una herramienta eficaz para enseñar a los estudiantes cómo mostrar y explicar su comprensión de los conceptos matemáticos.

En las próximas semanas, presentaré el diario de matemáticas e incorporaré algunas de las lecciones de Marilyn Burns, una educadora de matemáticas conocida a nivel nacional, en nuestras lecciones de matemáticas de Montessori. Seguiremos usando nuestros materiales de Montessori. Sin embargo, la necesidad de la intervención de diario es evidente porque, aunque todos los estudiantes se sienten cómodos utilizando los manipuladores Montessori para resolver problemas de fracciones, muchos no pueden transferir esa comprensión al dibujo de modelos representativos en las evaluaciones. Tampoco pueden articular su comprensión de las fracciones por escrito.

Todos los estudiantes participaran como miembros de la clase. Para comprender los resultados planeo analizar los datos obtenidos de los resultados de nuestras lecciones y evaluaciones. Tengo la esperanza que mediante el uso de diarios de matemáticas, que se enfocan en la práctica de dibujar y modelar fracciones y al escribir los pasos específicos necesarios para resolver problemas de fracciones, profundizaré la comprensión de su hijo/a en fracciones. Todas las estrategias implementadas y evaluaciones realizadas son parte normal de nuestra práctica educativa.

El propósito de esta carta es notificarle sobre esta investigación y darle la oportunidad de excluir los datos de su hijo/a (evaluaciones previas y posteriores, evaluaciones formativas semanales, diarios de matemáticas, y conferencias de maestros/estudiantes) de mi estudio.

> **Si decide que desea que los datos de su hijo/a estén en mi estudio**, no necesita hacer nada en este momento.

> **Si decide que NO desea que se incluyan los datos de su hijo/a en mi estudio,** anótelo en este formulario y devuélvalo antes del 10 de diciembre de 2018**.** Su hijo/a todavía va a participar en las lecciones, pero sus datos no serán incluidos en mi análisis.

Para tomar una decisión informada, tenga en cuenta lo siguiente:

- Estoy trabajando con un miembro de la facultad en St. Kate y una capacitadora de proyecto para completar este proyecto en particular.

- El propósito de este proyecto es fortalecer la comprensión de las fracciones de su estudiante y su capacidad para comunicar esa comprensión oralmente y por escrito. No hay riesgos previsibles en la participación de este proyecto.

- Voy a escribir los resultados de mi investigación. Sin embargo, ninguna información escrita incluirá el nombre de esta escuela, los nombres de alumnos o alguna referencia que permita identificar los resultados relacionados con un alumno en particular. Otras personas no sabrán si su hijo/a está en mi estudio.

- El reporte final de mi investigación será disponible electrónicamente en la biblioteca de la Universidad de St. Catherine. La meta en compartir mi investigación es para ayudar a otros maestros que también quieren mejorar su enseñanza.

- No hay penalización por no tener los datos de su hijo/a involucrados en el estudio; Simplemente eliminaré sus respuestas de mi conjunto de datos. Su decisión de permitir o no permitir el uso de los datos de su hijo/a no tendrá ningún impacto en su relación con Garden Place Academy o conmigo.

Si tiene alguna pregunta, no dude en ponerse en contacto conmigo. Puede hacer preguntas ahora o, si tiene alguna pregunta más adelante, puede preguntarme a mí o a mi capacitadora de proyectos, Alisha Brandon, Ajbrandon@stkate.edu, que estará encantada de responderlas. Si tiene preguntas o inquietudes sobre el estudio y desea hablar con alguien que no sea el investigador, también puede comunicarse con el Dr. John Schmitt, Cátedra de la Junta de Revisión Institucional de la Universidad de St. Catherine, al (651) 690-7739.

Puede quedarse con una copia de esta forma para sus archivos

_____ _____

Eileen Bechler Fecha

OPTAR POR NO: Padres / tutores, con el fin de excluir los datos de su hijo/a del estudio, firmen y devuelvan antes del 10 de diciembre de 2018.

NO quiero que los datos de mi hijo/a sean incluidos en este estudio

_____ _____

Firma de Padre/Guardian Fecha