Ensénames: Teaching Each Other to Reason Through Math Conversation in the Second Grade

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Question: What happens to my students' ability to express and defend their reasoning in math when I implement reciprocal (peer-to-peer) teaching?

Subquestions:

What happens to students' flexibility in the strategies they use?
What happens to students' ability to defend their reasoning mathematically?
What happens to students' math mastery over time?

Rationale:

With this research, I will investigate the ways that reciprocal teaching impacts my Language Learners' ability to express and defend their thinking in math. Over the last several years, math has become an area of strength at my school. Last year, we scored in the 99th percentile nationally on the NWEA test for students who met their growth goals. Within our transitional bilingual program, math tends to be an area of confidence for students who may struggle in literacy or elsewhere.

However, we also know that mastery-based judgments of students' abilities in math are limiting. Though my second grade students achieve high levels of mastery in a rigorous math curriculum, I see that their abilities to express their thinking clearly (with academic vocabulary and clear defense of strategies used) are extremely limited. All but one of my twenty-five students speaks Spanish as a first language. Though they can "do the math", they struggle to put names to the symbols or tools they use, write about or express their metacognitive processes, or defend their work against questioning. Likewise, it is perhaps more difficult for them to listen to and process the explanations of their peers, connect them to their own, and respond with question or critique. Currently, I see students describing their work with language like, "I used the thing because it is fast," or, "I just knew it", or "I used my brain to figure it out." While responding to the work of others, they are frequently limited to saying things like, "I agree because I did the same thing," or very low-level and inauthentic questions like, "Can you tell me more about that?"

Yet, we know that both the standards and the larger context require so much more of my students. While the CCSS (Common Core State Standards) are in effect in most curriculum programs, teachers have less direction as to how to implement the practice standards in their classrooms. These include eight "practices and proficiencies", including:

Make sense of problems and persevere in solving them.

Mathematically proficient students start by explaining to themselves the meaning of a problem and looking for entry points to its solution…They can understand the approaches of others to solving complex problems and identify correspondences between different approaches.

Construct viable arguments and critique the reasoning of others.

They justify their conclusions, communicate them to others, and respond to the arguments of others. Students at all grades can listen or read the arguments of others, decide whether they make sense, and ask useful questions to clarify or improve the arguments.

Model with mathematics.

Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. In early grades, this might be as simple as writing an addition equation to describe a situation

Use appropriate tools strategically.

Mathematically proficient students consider the available tools when solving a mathematical problem

In short, "doing the math" is not enough. More important, however, is that my students are just beginning on a much longer educational path that will demand that they are able to advocate for their thinking in many real and challenging ways. As students coming from low-income, minority, recently-immigrated families, they will face incredible challenges that require them to be able to defend their ideas, listen and respond to the diverse ideas of others, and draw connections between their experiences and those of their peers. I see the skills they can potentially grow within the context of math as being a bridge to this kind of self-advocacy later on.

Likewise, this kind of investigation in math may provide my colleagues and I some evidence-based understanding of best practices that can translate to literacy. As a bilingual program, we highly prioritize literacy and are currently struggling to implement the demands of the Common Core with our students, many of who come in reading below grade level. While my research findings will certainly help strengthen the math instruction of teachers at my school looking to move from simple mastery to the deeper demands of the standards, I also hope they can begin a conversation about how reciprocal teaching and meaningful conversation can help lift students' literacy abilities as well. I anticipate that the research I do in math will provide insight into the efficacy of different structures and feedback systems, and that we can use this information in other subjects as well.

School Context

This Fall marks my third year teaching second grade at Cesar Chavez Multicultural Academic Center, a CPS neighborhood school located in the Back of the Yards neighborhood on the Southwest side of Chicago. Our school serves pre-kindergarten through eighth grade students, though we are currently located in three separate buildings.

The area around Chavez is a busy place that reflects the culture of most of our students. Many small businesses line Ashland, though a few larger chains such as Walmart and Marshalls have recently moved in. While violence in the area surrounding the neighborhood persists, it is packed with students and their families visiting many of the local small businesses after school. Back of the Yards has a great deal of community organizations and family supports, as well as a very strong neighborhood council.

Our school serves 959 students, and though enrollment at many CPS schools is in flux, our school maintains high enrollment. Our students are about 95% Hispanic, with the rest being African American or white. Additionally, 99% of our student body qualifies as being from a "low income"

family. 49% of our population is classified as having limited English proficiency, though most students speak Spanish at home as a first language. Our school has a transitional bilingual program and all teachers grades PK-3 are bilingual certified, with most teachers in 4-8 having their bilingual certification or ESL endorsement.

While a late transitional model typically means that students phase from Spanish to English around fourth grade, our students begin English literacy in pre-school. In part due to the language demands of English language high-stakes testing, teachers work extremely hard in small groups and tutoring and integrate bilingual teaching best practices to support academic English and English literacy. In my own experience, this also means that many students do not become literate in their home language, though many parents do support Spanish reading at home.

Chavez continues to see both strong growth and strong attainment of goals on important assessments. This past year, we fell in the 99th percentile in both literacy and math growth as compared to other schools nationwide. Our goal attainment was in the 31st percentile in literacy (an area we continue to prioritize with language learners) and the 91st percentile nationally in math. For as long as I have worked at Chavez, we have been considered a Level 1 school.

Some of these outcomes may be attributed to additional academic programing and supports at Chavez. Our school has an extra hour of learning four days a week (totaling 25 extra days of instruction) as a part of our Additional Learning Opportunities program. Many teachers stay after school to tutor, and most students who are below grade level in grades 3+ attend some kind of weekend programming (through Supplemental Educational Services Tutoring or our partnership with the Rasheed Davis Charity program).

Our school also has many community partnerships that make it feel equal part community center. Each week, our families participate in the Healthy Kids Market, in which each family receives about thirty pounds of fresh produce. We also provide ongoing parent workshops, family literacy instruction, and parent volunteer opportunities. Our school also partners with the Kitchen Community, WITS, Common Threads, and the Latino Bar Association to provide enrichment opportunities to students. Additionally, after school programs like dancing, yoga, track, basketball, and others are offered throughout the year.

Chavez was deemed "Well-organized" by the Five Essentials report. In my experience, teachers are very happy to be working there, and have established strong relationships. While it is difficult to collaborate across three buildings, I have always felt a strong sense of teamwork at this school. It has also been my experience that teachers get the resources and support they need from our administration. This year, we took on a new assistant principal, principal in resident, and literacy specialist, and teachers are grateful for the additional feedback on their practice. Teachers are given a great deal of trust in their planning decisions, and while this sometimes results in a lack of consistency across grade levels, it also allows teachers to be innovative in their teaching.

In my own classroom, I work with 26 second grade students. About two thirds have been labeled as English language learners, but all but two speak Spanish as a first language. As mentioned above, we are a bilingual program but the majority of instruction – including literacy – occurs in English. I do use Spanish to support different students, as well as to build context for lessons. This year, I have students ranging from pre-reading all the way to level M (an end of second grade level), and their math skills range significantly. This leads us to teach in small groups for much of the day. I teach along with a student teacher that is spending the semester with us, which allows more students

to have much more differentiated instruction. We use the Saxon math scope and sequence, but adjust and supplement it heavily with more Common Core aligned resources that allow students to apply learning in authentic situations as much as is possible. We compose our own literacy units rooted in great children's books that reflect our students' backgrounds and experiences.

Literature Review

A visitor at my neighborhood public school, where 91% of students are Hispanic and 51% are classified as having limited English proficiency, would have every indication that students are excelling in math. Step into any classroom during math and see white boards flashing correct answers, students deeply engaged in math centers, and kids motivated to take on challenging work. In fact, last year's school quality performance report shows our students achieving in the 94th percentile among English Language Learners on the NWEA (Northwestern Evaluation Assessment) assessment. Yet, if a visitor paused to ask students to explain their work, justify their thinking, or re-teach a lesson to a peer, students' oral and written responses would be dramatically different from the work they produce. The Common Core Standards and related assessments like PARCC (the Partnership for Assessment of Readiness for College and Careers) highlight a new demand for students to be able to justify and rationalize their thinking through writing, purposeful listening, and problem-solving conversations – arriving at a correct answer is no longer enough. As such, for our students to continue to "show what they know", they must become proficient in not only math content, but the "language of math".

The Current Reality

According to the National Center for Education Statistics (2014), 9.1% of all public school students, an estimated 4.4 million children, were classified as English Learners (ELs). Despite this rapid growth of this population, teachers of language learners are often underprepared to serve these students. Gandara, Maxwell-Jolly and Driscoll (2005) found that 43% of teachers with 50% or more ELs in their classroom had received at most one professional development opportunity focusing on instructing ELs. Of teachers who reported having 26-50% ELs in their classrooms, half received no development. As such, the demand for research-based best practices for instructing ELs is higher than ever.

For ELs, the stakes of strong math achievement are high, and extend far beyond the classroom. According to Moses and Cobb, "The most urgent social issue affecting poor people and people of color is economic access. In today's world, economic access and full citizenship depend crucially on math and science literacy," (as cited in Roberts, 2009, p.29). They describe mathematics as a "gatekeeper and a sieve" that dictates student success, life experiences, and inclusion in society. Moses and Cobb state that students then lack the access to high school and college-level math courses, and subsequently do not have access to our technology-driven economy and many life opportunities (Roberts, 2005). Research from the National High School Center (2006) found that in 2005, only 61% of Latino students (many of whom are ELs) graduated from high school, 31% of those who graduate went onto complete some post-secondary education, and just10% of this group graduated with a bachelor's degree.

Lisa Delpit, who writes extensively on the intersections between race, language, and achievement, expands these outcomes beyond the academic world, explaining that students cannot

pass through this gate and into the "culture of power" without the "framework, tools, words, and ideas that underlie mathematics classrooms" (as cited in Roberts, 2009, p. 31). Khisty and Morales state "I (as cited in Roberts, 2009, p.32). With this in mind, my research seeks to identify the way that one teaching strategy, peer assisted learning (PAL) helps language learners develop their academic English proficiency while supporting math content achievement.

The Language of Math

Our lack of understanding in how to best support ELs results in many of these students being pushed into low-level math courses that focus on basic skill drills in place of higher-level thinking. Yet when ELs perform poorly on district or state assessments, it is difficult to isolate their achievement to lagging content skills or knowledge or their language abilities. Roberts (2009) calls for teachers to help develop lasting and transferrable English language skills in their students through explicit teaching of math discourse. She highlights skills like framing conjectures, using technical language, revoicing ideas, and following conversational norms – all skills that help students access Delpit's "Culture of Power" beyond the realm of math. Rittenhouse (as cited in Roberts, 2009, p.32), supports this kind of metacognition, noting that "In order to learn the structure of the mathematical discourse, students need opportunities to learn how the discourse they are using works; they need to 'talk about the talk.'"

Kang and Pham (1995) state that language learning and mathematical concepts should be taught in an "intertwined" way, and argue that students with weak language skills actually need more experience with mathematical language. Kang and Pham describe a "mathematics register" of features that students must master to be able to listen to, present, and argue about math thinking. Beyond academic vocabulary like "divisor", students must master everyday vocabulary that take on new meaning, like "rational" as well as math concepts that can be represented by many words (i.e. add, plus, sum). Students must gain proficiency with syntactical structures like comparatives (n times as much as) and prepositions (divided by; take one third of). They must also be able to comprehend what Kang and Pham describe as "logical connectors", or text that includes relationship signals, such as cause and effect language, chronological language, or reasoning language. I currently see this as a major barrier for my students when they attempt to justify their thinking. While their "math" is correct and complex, their explanations use vague pronouns to describe their tools or strategies, are full of imprecise vocabulary references, and are often illogically presented when students lack the connecting words or verbs to describe their thinking process. The result is that students struggle to learn from students who are strong mathematicians with low language abilities. As such, it is important to implement structures that allow language-learning students to scaffold their conversation with support from students with more developed language skills.

Peer Assisted Learning as Language Instruction

While students individually develop Kang and Pham's mathematical registers, providing space for mathematical discourse is crucial. Peer assisted learning provides an excellent context in which to develop these skills. Kang and Pham describe discourse competencies that develop functional uses of language that support students' access to the "culture of power" beyond mathematics:

- Heuristic discourse (tell me why) allows students to practice inquiry to explore real world problems

- Imaginative discourse (let's pretend) helps students to imagine, conjecture, and hypothesize
- Informative (let me tell you) supports students in teaching new information to others
- Representative function (tell how things are) gives students the tools to represent, model, and clarify relationships and meaning
- Directive function (do this) teaches students to request others to do things

These discourse features are used in conjunction with skills like classifying, evaluating, initiating questions, raising conjectures, convincing others, and using math argumentation. Kang and Pham call teachers to encourage students to use their own linguistic backgrounds in developing these discourse skills. They state that students can make sense of new concepts in learning if they are allowed to link it to familiar language. In this way, they encourage classroom structures (such as PAL) that maximize opportunities for students of similar backgrounds to share in the co-construction of meaning. In my own classroom, I want my students to not only be able to justify their thinking in math, but in response to literature, and in advocating for their ideas beyond an academic context. Each of these competencies empowers students with the skills to actively listen to and compare perspectives, advocate for and convince others of their methods and rationale, and lead others towards finding solutions to complex problems. These competencies not only help them access rigorous math, but help them gain entrance to Delpit's "Culture of Power" in our larger world (as cited in Roberts, 2009, p. 31).

Much research supports the use of peer assisted learning techniques, particularly in the context of language learners. Much of this research is rooted in Vygotsky's theories of constructivism, in which he hypothesized that students more deeply internalize conclusions that are made in group contexts (Mueller and Maher, 2009). He suggests that what students "can do with the assistance of others is more indicative of their mental development than what they can do on their own" (as cited in Mueller & Maher, 2009, p.11). This could mean learners supporting each other with the questions or missing pieces of information necessary to solve a problem, or working together to hypothesize, refine, challenge, and conclude about mathematical ideas.

Gerena and Keiler (2012) describe a "Peer Enabled Restructured Classroom", in which peer assisted learning is a central strategy. They describe the multiple positive impacts on both achievement and language development for "tutors" and "tutees" alike. In addition, reciprocal teaching that places students with "near-peers", or a tutor/tutee who are close in language or content ability level, can be even more beneficial, as tutors have recently studied and struggled with the material themselves. A powerful study led by S and Sison (1995) examined the effect of Instructional Conversations (ICs), or student-led math discourse, on the amount of student talk, development of content-based language, and strength of communication features. They found that when students were given time for structured discourse, students ultimately accounted for 50% of the classroom utterances (a shift from traditional, teacher-heavy math lessons). Additionally, student participation became increasingly evenly distributed over time, indicating that even newcomers and students with lower language skills were meaningfully engaged. Over just four IC-based lessons, the students' use of content vocabulary increased from six utterances to 48 utterances within the lesson, and the measure of "appropriate" (on task, responsive) discourse functions rose from 88% to 96%. This research supports the idea that IC, or PAL, has a sizable impact on language learners' abilities to co-construct meaning while developing important language skills.

While new demands from assessments and national standards raise the stakes for my students' language development, I remain motivated to help students continue to show what they know. Peer assisted learning provides an opportunity for Language Learners to do this within a student-centered, highly scaffolded, and real-world context.

Summary of Data Collection Methods

Research data was collected in a second grade classroom of twenty-five students. Twelve of these students are labeled as English Language Learners (ELLs), but twenty-three speak Spanish at home as a first language. (Others are not labeled as such because parents chose to opt out of the bilingual program or because students have tested out based on language proficiency.) Within the larger class, my research focuses in on eight students who serve as a representative sample of a cross-section of students divided based on language abilities and strength in math content. In the chart below, you'll note the students, their national percentile rating in math in the beginning of the year (based on the NWEA assessment), and their ACCESS English proficiency score in first grade.

High Math, Low Language	High Math, High Language
Araceli (37%/4.5) Yadiel (26%/ *Not listed as ELL, but language is low)	David (59%/4.8) Alexia (73%/Non ELL)
Low Math, Low Language	**Low Math, High Language**
Cynthia (37%/3.7) Laura (4%/2.5)	Mayeli (56%/3.7) José (46%/4.5)

Additionally, data was compiled within multiple contexts:

- Math Message: All students complete a math message including spiraled skills (time, counting money, place value) in the morning as a review structure. At the onset of math, students identify the questions they struggled most with. We choose two as a class, and students get into peer teaching groups of three students. They take turns explaining their solution or best approach and asking questions of each other's work. Students then volunteer to model their solutions on the SMART Board.
- Math Journal: Students open the lesson with a math journal prompt about three days a week. These are challenging problems that allow for multiple paths to a solution. Students solve – using whatever strategies and manipulatives they choose – while I circulate to collect data on students' approaches. Students then join heterogeneous groups and follow a protocol for sharing their work and questioning/critiquing the work of others. We then choose two to three students to present the strategy they found to be most effective to the class, while other students question and respond to their work. Students also use a numerical score before and after the group time to quantify how well they understand. This tool helps students to stay metacognitive, while giving me a read on the efficacy of this structure. Most student work and video samples come from this time.

1. Student Math Journals (see above): I review samples of journals across the class weekly, but I took samples of journals from the four subgroups of students about every three weeks. I use a rubric to rate students' growth across five domains: Strategy Use, Modeling, Vocabulary Use, Process Writing, and Reflection. The strategy use and modeling strands reveal information towards subquestions one and two (1. What happens to students' flexibility in the strategies they use? 2. What happens to students' ability to defend their reasoning mathematically?). The vocabulary use, process writing and reflection helps illuminate growth towards subquestion three (3. What happens to students' math mastery over time?) Data collected is organized in three ways:

- Individual student's growth in each area of the rubric (and overall) over time
- Subgroup growth in each area of the rubric (and overall) over time
- Overall growth for each area of the rubric over time (when examined for the whole subgroup of eight students)

2. Video Recordings: These video recordings come from the math message and the math journal structures mentioned above. Within the math journal conversations, I focused in on small groups of my subgroup of eight students. The video samples reveal many things: student engagement, the strength of student questioning/discourse, students' abilities to explain their modeling and thinking, etc. In particular, they provide evidence towards the principal research question and question 2 (What happens to students' ability to defend their reasoning mathematically? I assessed student recordings on a math conversation rubric that I developed with my students after we watched video of high-performing students engaged in math conversation. Students are rated along three criteria: Sharing ideas and time, teaching, and questioning. Again, data can be cut three ways:

- Individual student's growth in each area of the rubric (and overall) over time
- Subgroup growth in each area of the rubric (and overall) over time
- Overall growth for each area of the rubric over time (when examined for the whole subgroup of eight students)

3. Student Performance Tasks: I administered three performance tasks (quarterly beginning in mid-first quarter) asking students to respond to an open ended problem requiring flexibility and innovation.) Students respond by identifying a strategy, modeling their thinking/problem solving, and then explaining their work in writing. These performance tasks are assessed along the same rubric as math journals.

4. Student Mastery: Students take unit assessments once every three weeks. I use the results of these assessments – most of which include some open-ended questions in which students must defend their reasoning or critique that of a peer – to gauge whether mastery increases over time as reciprocal teaching is implemented. I track this data to understand progress towards subquestion 3: What happens to students' math mastery over time? I can use this data to look at whole class trends, trends across language and/or math levels, and to look at growth within my subgroup of eight students.

5. Teacher Journal: I reflect in a teacher journal about once a week. Early on in my research, this journal became very focused on my research question. Quotes, observations, and data recorded in this journal gives insight as to how well new structures or approaches are working and in what areas I need to continue focusing.

Research Cycles: My research began near the end of September, through the structures of math journaling described above. At this time, I began using math journal conversations two to three days a week, and collecting video of student conversation about once every two weeks. I also began collecting data around mastery and performance tasks. However, September and October really served as a time to collect baseline data around the skills students were entering second grade with. During this time, I worked to reinforce expectations around conversation, introduce and improve on journaling procedures, and build the mindsets necessary for students to take risks during math.

Around January, I began looking critically at the data and realized that students were *not* showing the growth I'd hoped them to show, particularly in the areas most related to language (process-writing, vocabulary use, and reflection.) The following is my journal entry from January 7:

Qualitatively, I feel that the quality of conversation in my class has improved markedly; more students are participating, I hear more content vocabulary being used, and I see higher levels of engagement across multiple subgroups of students. I finally feel like most students are able to engage enough to listen and at least preliminarily respond to their peer's thinking. So, I was really shocked by how little growth I saw in students' journals.

Typically, while students are writing the reflection, I try to use the few quiet minutes to follow up with a student who was really lost (to prep them for the beginning of the lesson), or to hear out the idea of a student who maybe did something innovative that the rest of the class may not have been ready to benefit from. As such, I often don't check in with students' writing/reflections, which made today's review of the data really surprising.

I see little to no growth in students' journal writing. Their strategy use is improving greatly – more students are taking risks, trying multiple strategies, and demonstrating flexibility with applying things we've learned before to new situations. This is great, and is certainly one of the outcomes I was working towards. However, I see that the majority of students are not writing much at all about their modeling/problem solving, and some students are, but continue to lack strong process writing and vocabulary. The one group that did show growth here were my lowest students, which seems promising. Initially, students like Laura and Cynthia didn't even attempt problems, but I know see that they not only always have some kind of solution, but also can generally describe their thought process. Why they certainly don't meet expectations on the rubric I developed, they do show the most growth.

Really though, the results make a lot of sense. Reflecting on my own instruction, I've made many assumptions (that I know are incorrect) around conversation skills and writing skills developing in tandem. I know that they do not, but I've only highly prioritized the conversation growth. Looking at student journals really didn't reveal anything other than I need to be as explicit and disciplined in teaching writing about math as I am writing about literature (or other kinds of writing assignments), in which I break down all of the elements of strong writing over days and days.

Moving forward, I've made a plan to do just that. In the coming week, I've broken down the journal writing piece into multiple small components – transition language, justification of strategy, sequential writing, use of vocabulary, etc. – and plan to devote time each day during math teaching this kind of writing. Like I do with students' literacy journals, I also plan to have students begin analyzing each other's journals on a simplified version of the rubric I use. My hope is that this will help them put the growth I'm seeing in their conversations back onto paper more effectively.

This marked the second phase of my research, in which I strategically prioritized growth in the areas of process writing, vocabulary use, and reflection. Some of the steps I took included:

- ☐ Systematically breaking down the smaller skills embedded in those three areas into teachable objectives such as: *Integrate transition words and sequencing language when describing a process; Use vocabulary to add specificity to descriptions; Revise writing to show process, not tell.*
- ☐ Integrating writing mini-lessons in the beginning of math lessons for about two weeks to model, and practice these discrete skills.
- ☐ Using feedback protocols to help students reflect on and improve their journals.
- ☐ Creating a student-friendly rubric (with students) for them to use to assess their own work.
- ☐ Strategically building in vocabulary through more bilingual best practices (i.e. introducing words with realia, using syntactic mapping to understand the meaning of words, doing relationship mapping between words, etc.)
- ☐ Videotaping student conversations and sharing with the whole class to practice turning the conversation into a written reflection.

As a result of these interventions, I saw students grow much more during the months from December to January in these three targeted areas. Students' growth towards both cycles of the math journal data are outlined in tables 1 and 2 below, and described in the section Written Reasoning below.

This time also made me think more critically about what my research was *not* measuring, such as students' abilities to take risks, communicate their ideas in front of the class, follow a discussion topic through many exchanges, and build on the ideas of their peers. I decided to collect data in a secondary way, through videotaping small group conversations. I collected video about once every two weeks on a subgroup of students that represented each of the four subgroups above. I continued these video recordings bi-weekly through March, and was able to transcribe conversations to collect more qualitative data. Further explanation and data are outlined in the section Oral Reasoning below.

Introducing Data and Findings: In the sections below, I will introduce three data tables that measure journal writing growth, performance task growth, and mastery/assessment information. Following the tables, I will integrate the data collected into a more qualitative description of each student's journal, performance task, and assessment mastery growth for both the first and second cycles of research. Following that section, I will share qualitative data and observations collected during the videotaped conversations.

Table 1: Student Journal Growth

This table measures student growth in their math journals from September to March. Each of the five rubric areas (strategy use, modeling, vocabulary, process writing, and reflection) were placed on a four point scale. Growth is measured from the beginning of year (September) baseline score to the last journal in March.

	Low Math, Low Language				Low Math, High Language				High Math, Low Language				High Math, High Language			
	Cynthia		Laura		Mayeli		Jose		Araceli		Yadiel		Alexia		David	
	Sept.	End Avg.	Sept.	End Avg.	Sept.	End Avg.	Sept.	End Avg.	Sept.	End Avg.	Sept.	End Avg.	Sept.	End Avg.	Sept.	End Avg.
Strategy Use	2	2	2	4	2	3	1	2	3	4	1	2	3	4	3	4
	Growth: 0		Growth: +2		Growth: +1		Growth: +1		Growth: +1		Growth: +1		Growth: +1		Growth: +1	
Modeling	1	3	2	4	1	3	1	3	2	4	2	2	1	4	2	4
	Growth: +2		Growth: + 2		Growth: +2		Growth: +2		Growth: +2		Growth: +0		Growth: +3		Growth: + 2	
Vocabulary	2	1	1	1	1	1	1	3	2	3	2	2	1	4	2	1
	Growth: - 1		Growth: + 0		Growth: 0		Growth: +2		Growth: +1		Growth: +0		Growth: + 3		Growth: - 1	
Process Writing	2	1	1	1	1	1	1	2	2	3	2	2	1	4	1	1
	Growth: -1		Growth: +0		Growth:0		Growth: + 1		Growth: + 1		Growth: +0		Growth: + 3		Growth: +0	
Reflection	2	3	1	3	1	2	1	2	2	3	2	2	1	4	2	2
	Growth: +1		Growth: +2		Growth: +0		Growth: +1		Growth: +1		Growth: +0		Growth: +3		Growth: +0	
Overall (of 20 pts)	9	10	7	13	8	10	5	12	11	17	9	10	7	20	10	12
	Growth: +1		Growth: + 6		Growth: + 2		Growth: +7		Growth: + 6		Growth: + 1		Growth: + 13		Growth: +2	
Subset Averages	Overall Score (of 20): 11.5 Growth: +3.5				Overall Score (of 20): 11 Growth: +4.5				Overall Score (of 20): 13.5 Growth: +3.5				Overall Score (of 20): 16 Growth: +.75			

Table 2: Performance Tasks

This table measures student growth in their performance tasks from September to March. These tasks were measured on the same rubric as math journals with the exception of reflection, as they were an independent task. Each of the four rubric areas (strategy use, modeling, vocabulary, process writing) were placed on a four point scale. Growth is measured from the first performance task (December) baseline score to the last performance task in March.

	Low Math, Low Language				Low Math, High Language				High Math, Low Language				High Math, High Language			
	Cynthia		Laura		Mayeli		Jose		Araceli		Yadiel		Alexia		David	
	Sept.	End Avg.	Sept.	End Avg.	Sept.	End Avg.	Sept.	End Avg.	Sept.	End Avg.	Sept.	End Avg.	Sept.	End Avg.	Sept.	End Avg.
Strategy Use	2	2	2	3	2	3	2	3	3	3	3	3	3	4	2	2
	Growth: 0		Growth: +1		Growth: +1		Growth: +1		Growth: +0		Growth: +0		Growth: +1		Growth: +0	
Modeling	2	3	2	2	1	4	2	2	3	3	3	3	2	4	2	2
	Growth: +1		Growth: + 0		Growth: +3		Growth: +0		Growth: +0		Growth: +0		Growth: +2		Growth: + 0	
Vocabulary	2	2	2	2	1	3	2	3	3	3	2	3	2	4	2	2
	Growth: +0		Growth: + 0		Growth: +2		Growth: +1		Growth: 0		Growth: +1		Growth: + 2		Growth: +0	
Process Writing	2	2	1	1	1	3	2	3	3	2	3	3	2	4	2	2
	Growth: 0		Growth: +0		Growth: +2		Growth: + 1		Growth: -1		Growth: +0		Growth: + 2		Growth: +0	
Overall (of 16 pts)	8	9	7	8	5	12	8	11	12	11	11	12	9	16	8	8
	Growth: +1		Growth: + 1		Growth: + 7		Growth: +3		Growth: -1		Growth: + 1		Growth: + 5		Growth: +0	
Subset Averages	Overall Score (of 16): 8.5 Growth: +1				Overall Score (of 16): 11.5 Growth: +5				Overall Score (of 16): 11.5 Growth: +0				Overall Score (of 16): 12 Growth: +0			

Table 3: Student Mastery over Time

This table shows student mastery from September (Unit 2) through March (Unit 18), as measured by teacher-made assessments covering our math curriculum. As content became more rigorous over time, so did the assessments. The first unit (Unit 1) was not included because it covered review material from the previous grade level. These assessments were graded on a 100-point scale.

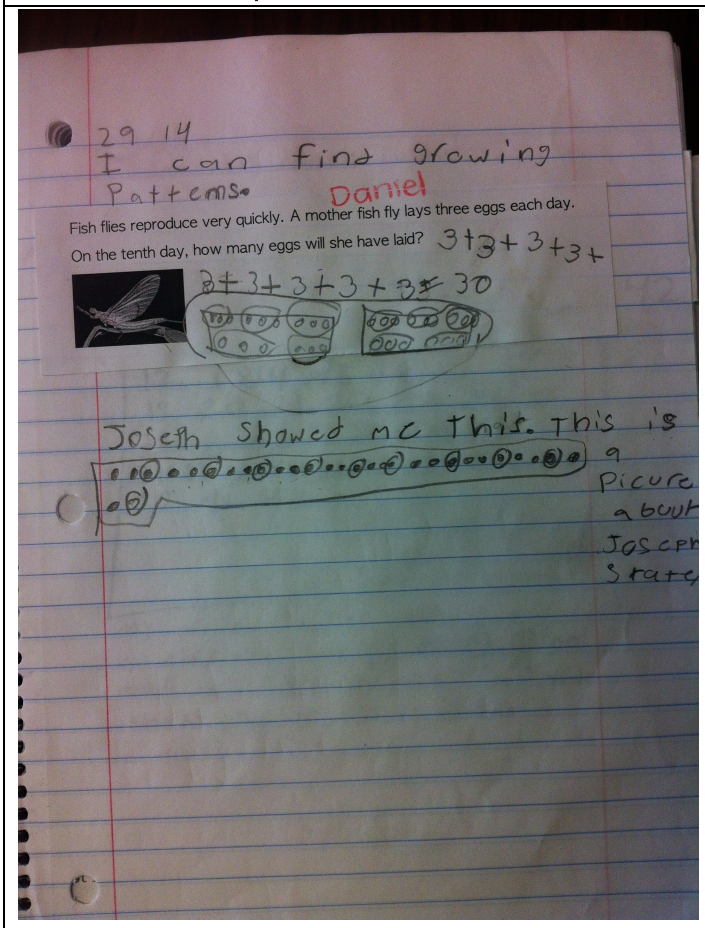
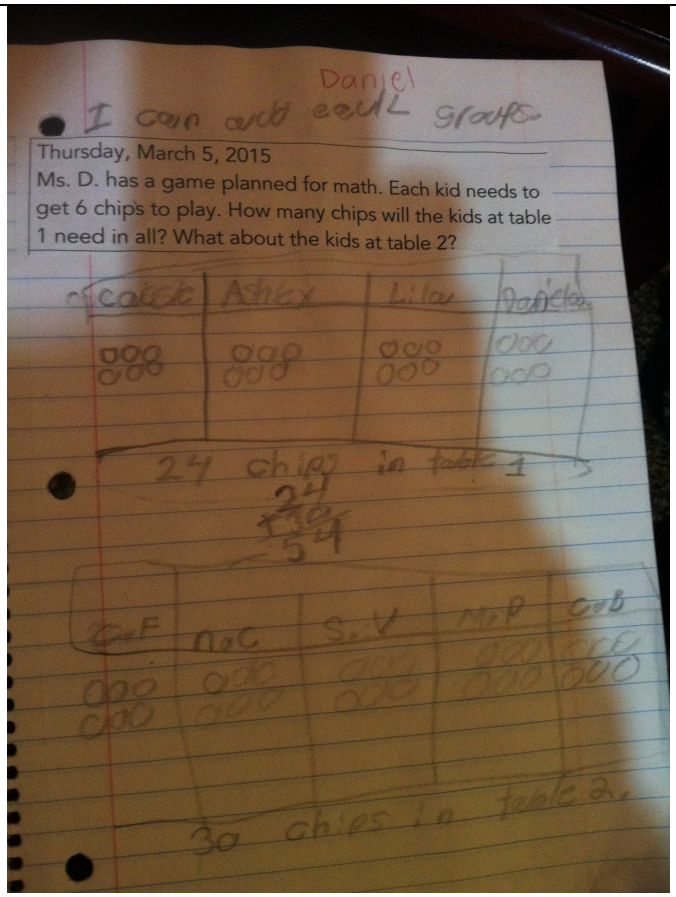
	Unit 2	Unit 4	Unit 6	Unit 8	Average – Pre-Explicit Instruction	Unit 10	Unit 12	Unit 14	Unit 18	Final Average Mastery	Growth – middle avg. to end avg.
Cynthia	75	78	72	91	79	75	66	63	80	71	-8%
Laura	70	90	84	85	82	72	76	64	83	74	-8%
Mayeli	97	92	83	85	89	90	94	92	83	90	+1%
Jose	85	84	68	77	79	70	80	87	67	76	-3%
Araceli	82	90	78	93	86	80	88	92	78	85	-1%
Yadiel	94	94	77	89	89	80	88	88	72	82	-7%
Alexia	100	92	87	100	95	85	94	92	100	93	-2%
David	91	82	88	100	90	85	78	91	86	85	-5%

Table 4: Assessment Growth over Time

This table includes information from the MAP/NWEA assessment taken in the beginning of the year (September) and the middle of the year (January). This assessment is administered to all second through eighth graders (and in some cases, kindergarteners and first graders) in our district. It is also administered in many districts throughout the nation. The assessment is norm-referenced, meaning that students are given a scaled "RIT Score" upon completion of the test. This RIT score translates to a national percentile ranking, comparing students with other children at their same grade level. For instance, if a student is placed at the 45th percentile, it means that 55% of students at the same grade level received a higher RIT score. The amount of points students grow at each grade level changes significantly – for instance, a second grader might be expected to grow around 15 points in the course of a year, while an eighth grader should only grow three or four). For this reason, I find it more useful to look at students' percentile rankings and growth throughout the year than their RIT score alone. In the table below, you will see students' beginning/middle of the year RIT scores and growth, as well as their beginning/middle of the year percentile scores. Consider two examples:

- *Mayeli's middle of the year RIT score (185) is on-par with where a second grader should score. However, she showed -1 percentile growth at the middle of the year, because other students who started at her same level grew more than she did.*
- *Laura, however, has a RIT score more indicative of the end of first grade (180). Despite this, she grew 19 percentile points to the middle of the year*

	BOY RIT Score	BOY Percentile	MOY RIT Score	MOY Percentile	EOY RIT Score	EOY Percentile	RIT Growth	Percentile Growth
Cynthia	174	37	184	45	187	37	13 points	0
Laura	156	4	180	33	193	55	37 points	51
Mayeli	180	56	185	48	198	68	18 points	12
Jose	177	46	184	45	192	52	15 points	6
Araceli	174	37	181	36	200	76	26 points	39
Yadiel	170	26	186	52	193	55	23 points	29
Alexia	186	73	194	75	213	96	27 points	23
David	181	59	189	61	196	65	15 points	6

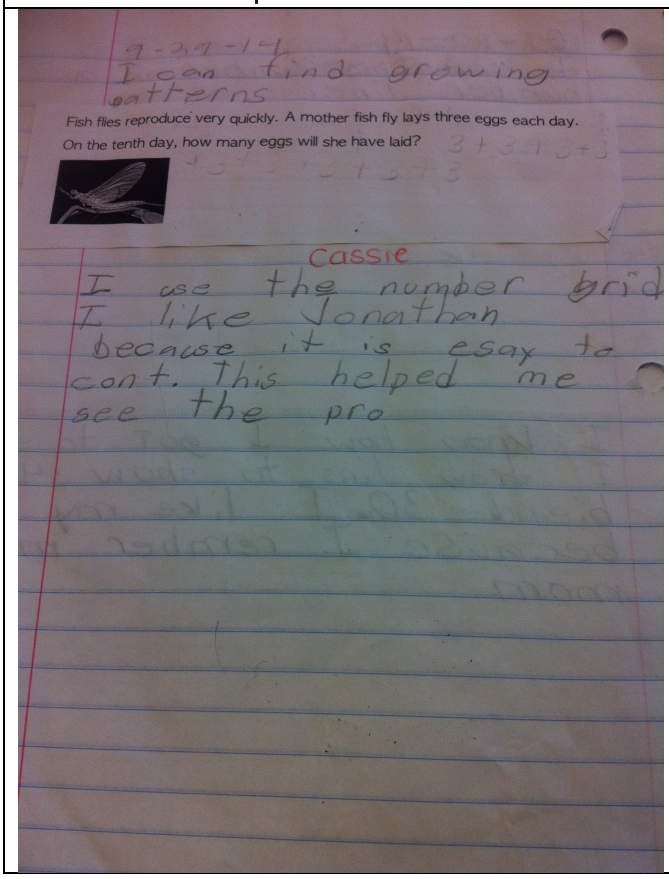
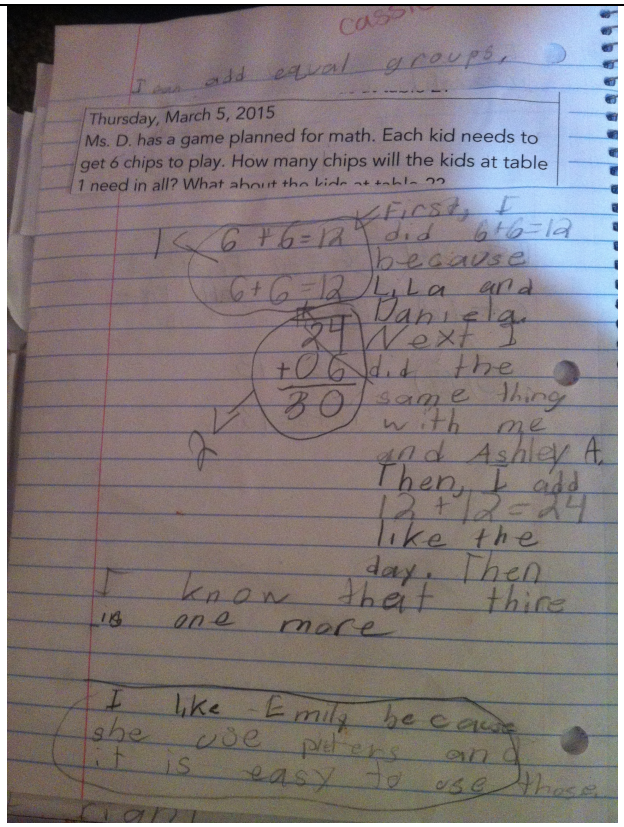
September Journal	March Journal
	

Performance Tasks: David did not show any growth in his performance tasks.

Mastery and Assessments: David showed negative growth from the beginning to the end of the year in his assessment mastery (-5% points). He also demonstrated relatively limited growth on the NWEA assessment (only 6%).

Qualitatively, David's journals were almost always done with high levels of reflection and accuracy, but he did not engage in this process like Alexia did. Near the end, he was still slightly nervous about taking risks and still struggled to clearly share his thoughts in front of the class. I believe this may explain part of why he grew in his modeling and strategy selection but not in the areas of language or writing. I learned from this process that David has very strong procedural math, meaning that if he has a formula or algorithm to follow, he is very successful. This has allowed him to excel in math on assessments and daily work. However, he lacks the confidence that students like Alexia and Mayeli have to take risks to share their ideas, meaning that he did not gain as much practice in the expression of those ideas as some other students did.

Alexia: Alexia showed tremendous growth in modeling, vocabulary, process writing, and reflection (all three points) and amazing growth overall (13 points!) Overall, Alexia grew more than any other student.

September Journal	March Journal
	

Performance Tasks: Alexia was one of the only students who showed significant growth in her performance tasks, showing two points of growth in three of the four areas. This was very consistent with her journal growth.

Mastery and Assessments: Like David, Alexia made some negative growth (-2%) on her assessment mastery. However, in contrast, she grew 23 percentile points on the NWEA test (ending at a grade level equivalent of above fifth grade!)

Alexia responded tremendously to the journaling and math conversation structures. Her growth far exceeded that of other students and was consistent in every area of our work in the journals. Alexia makes me think about other "soft skills" that these rubrics and measurement tools do not capture, such as stamina, grit, and self-motivation. I have never seen a student persevere through math challenges the way Alexia does; Her journals are filled with multiple attempts at the same problem, efforts to solve the problem in new and innovative ways (even if there are easier routes to an answer) and consistent tries at integrating recently-learned strategies. These are skills that I do not see in students like Mayeli or Araceli. Alexia already had an incredibly strong math content foundation, but I believe that these skills allowed her to excel at such an astounding rate – and also highlight the differences between her and David (who has similar content knowledge).

Trends for David and Alexia (High Language, High Math)

- **Positive Growth:** These students both grew significantly in modeling, but Alexia really grew in all areas relative to David.
- **Negative Growth:** Alexia did not decline in any area, though David dropped one point in vocabulary use and did not show growth in process writing or reflection.
- **Relative Overall Scores:** These students had the highest overall scores in the areas of strategy use and modeling (4 points of 4), and Alexia had a perfect rubric score in all areas in March.
- **Mastery and Assessments:** Both students showed small negative growth on their assessments, and their growth on the NWEA assessments were very disparate.

From student journals, I was quickly able to determine that across all subgroups, math journals and the subsequent class conversations helped to support positive growth in strategy use and modeling. Every subgroup showed the most growth in these two areas, with the exception of Alexia and David (high math and high language), who had very high scores in these areas to begin with.

From these observations, I implemented much more specific instruction around the elements of process writing and reflection. Some strategies used included:

- Explicit modeling of process writing
- Strategic teaching of elements of the rubric such as transition words, labeling and the integration of vocabulary.
- Peer feedback protocols to respond to students' writing about math – whole group and in peer partnerships
- Transition from whole group math journal conversations to more frequent small group conversations.

Oral Reasoning

One way to monitor student growth in the areas of process writing and reflection was through more frequent small group conversations in response to math journals. In this protocol, students shared their approach to solving while three other students (in a heterogeneous group) asked questions or shared reflections and comparisons. I focused in on one small group of students who represented the same subsets as above. Three of these students (Laura, Jose, and Alexia) were also a part of the written response (Journal) research subset. However, I included Anthony as a representative of the high math, low language group in place of either Araceli or Yadiel.

Laura: Laura grew significantly in her ability to explain her strategies – growing from 1 point in December's conversation to 3 points in March. Laura also grew significantly in her use of technical vocabulary – in terms of the math vocabulary used as well as the vocabulary used to support her explanation of her process. As evidence of this growth, consider how she introduced her strategy on December 2nd: *"What I did is I put little balls. Well, they're coins. I put this here. Then I count this. Then I make this. I count it. Then I was confused about my own work because I didn't know what did I did. I think I count too much. I didn't know what to do. So I counted again."* In comparison, her

introduction on February 9th was more succinct and clear: *"I put those lines – it's 10, and 3 + 3 is 6. Then I put them together, and it was this number. Then I mixed them up, and I got the same answer."*

Finally, the quality of Laura's responses showed much deeper comprehension of other's strategies, though her vocabulary remains limited. On January 8th, when Jose asked for clarification, Laura said, "*I don't know what to say."* By February, she was able to say, *"I like your strategy Jose. And, if you make the little squares, I make the little things that go for decorate, and I just wrote like that, and it helps me a little bit to do this ones."* While this shows strong comparison, it doesn't integrate vocabulary from the lesson.

Jose: These interventions supported Jose's conversation most in the area of vocabulary and his ability to reflect meaningfully. In December, Jose described his strategy like this: "*I saw this in the problem, so I knew to put this here."* However, in February's conversation he was more specific: "*She put these two numbers on the bottom together to equal 10, and then the sides of 3 together to equal 16."* He grew from one point on the rubric to three points in vocabulary use from December to February.

Jose's most notable improvement was in his ability to show deep comprehension in his reflections and questions. While Jose almost always responded within small groups, his questions initially did not show meaningful reflection. For instance, in response to Laura's strategy in December, Jose said, "*I can't say anything,"* and in January, he still asked very non-specific questions: "*Can you tell me a little bit more?"* However, by March, his questions improved from a one on the rubric to a three, as evidenced by this comment: "*I had a similar answer to you. Because I put 5 and 5, and I got ten. Then I put 3+3 and I got 6. And I put the 10 and the 6 together and I got 16. So it was the same but I used a number line."*

Anthony: Like the other students in his group, Anthony showed significant growth in his strategy use. Initially, he was able to use meaningful vocabulary, but not in a way that shared his strategy or his process clearly. In December, he introduced his work as follows:

> "*I put some lines to tell how the tens were, and how the ones are. If I do the 20, I need to put two tens. So people could know what is the 20 and the 2 for. And then I put the 9, so they could put 9 ones. Right here I put the other numbers up here so I could see it – and I put 61, and the 6 is a ten, and I put the 9 with a 1, and that equals 10, so I combine them and they equal ten."*

Alexia: Alexia began this intervention with very high language and math abilities, and I think as a result, she often engaged less in these conversations because her strategies were at a much higher level. (This, in turn, makes me wonder about *who* these conversations benefit and do not benefit.) Because she started out at a high level, Alexia showed little growth but very consistently high scores in all areas of the conversation rubric. Her strategy from February illuminates some major differences in the level of her vocabulary and clarity of procedure relative to other students:

"I took the two fives from the top and the bottom, and 5+5 = 10, and I put 10 + two threes on the sides, and 10 + 6 = 16. I knew that the border was 23, so I put 20-16 = 4, and I knew that 4 was what was left because 16 was all around the border."

On the whole, the group conversations improved markedly in the number of exchanges, number of students involved, and ability of students to explain their thinking clearly enough to allow others to reply. Consider the two exchanges below:

December 12

Laura: What I did is I put little balls. Well, they're coins. I put this here. Then I count this. Then I make this. I count it. Then I was confused about my own work because I didn't know what did I did. I think I count too much. I didn't know what to do. So I counted again. I get the answer 95 cents. *Teacher: Any questions:* *Anthony: No. Oh yeh. How did you – did you divide them, or add them together?* *Laura: This is part two.* *Anthony: Did you add them together or separate them?* *Laura: I separated them, and when I was done, I count them.* *Jose: That's all the questions we have.*	• Teacher prompts questioning • 6 exchanges • 3 students involved • Questions are neither targeted nor do they show deep comprehension

March 12

Anthony: The way I did it, was I looked for curved edges, and some worked. Then I tried to put some more curved edges and it didn't work. Then I used triangles, like this. Then I kind of connected them together and I started right here and I kind of covered it. *Laura: I think Anthony that that won't work. Those little pieces will make new shapes. It would help to use straight lines.* *Anthony: That's true. I kind of switched the shapes together. I kept trying with the triangles and it kind of worked. Right here it worked well but right here it didn't.* *Jose: I disagree with your strategy because these cards covered this part and this part, but if you try to add something new, like with a curved shape, it won't work. I could put these ones together with the straight edges, but we need more shapes with more straight edges.* *Laura: My strategy was to look for the triangles. Some of them were like that, some of them were like that. I tried ones to see if each ones work. But it was still hard to fill it up.* *Maybe we could cut the shapes and just use the ones that are straight.* *Anthony: Yeh, like the triangles.* *Jose: But I didn't agree with the triangle.* *Alexia: I think that I would use squares.* *Anthony: But which ones, those are different sizes.* *Alexia: We could put these squares into an X, and put one square here, one there, and another over there.* *Jose: That's the – that's what we should do.*	• No teacher involvement • 11 exchanges • all students involved • questions are ones that compare, clarify, and help to extend • The group reaches a consensus as a result of the conversation • Evidence of several students' opinions being changed by each other's strategies.

Conclusions

1. What happens to students' flexibility in the strategies they use?

I measured students' flexibility quantitatively through their ability to choose meaningful strategies while problem solving in their journals and performance tasks, and through their abilities to show meaningful comprehension through strong modeling. Students' application of math strategies became more accurate and more flexible over time. Across all subgroups, students averaged 1 point of growth on a 4-point rubric in their strategy use from September to March in their journaling. Likewise, they grew 1.9 points in their ability to model their thinking, demonstrating that they are not only able to select a meaningful strategy, but can also apply it with deep thinking.

Within these two areas of the journal rubric, students with low math skills and high language ability (Mayeli and Jose) seemed to grow the most (and the most consistently). Students with low math abilities and low language (Cynthia and Laura) grew significantly in both of these areas. This seems to suggest that journaling helped students with low math abilities to strengthen their strategy use and their ability to model their thinking. Qualitatively, I saw that these students were able to identify

strategies that made sense, given the problem, and break down the steps of using that strategy enough to model it concretely.

2. What happens to students' ability to defend their reasoning mathematically?

I measured students' defense of their strategies through their "process writing" or ability to write about the strategies that used. I think that vocabulary usage and reflection are secondary data sources, but are difficult due to inconsistencies. Sometimes, I did not have students write reflections, and certain lessons lend themselves to deeper vocabulary use than others.

Over time, students writing improved the least (+.5 points on the rubric), tied with vocabulary use. They did improve 1.1 points on average in their abilities to reflect. Students who grew the most in their ability to explain their thinking were the students with both high language and high math abilities, followed by students with high language and low math skills. Conversely, students with low language and low math, and students with high math and low language showed *negative growth.* This suggests that journaling did *not* positively impact students with low language to express their work in writing.

However, I did see great improvements in the data gleaned from video conversations in the area of vocabulary. This was particularly true for students who are low in math.

	Laura (Low Language, Low Math)	Jose (High Language, Low Math)	Anthony (Low language, High Math)	Alexia (High Language, High Math)
Vocabulary Use	+2 points	+3 points	+1 point	+1 point
Process Explanation	+ 0 point	+0 points	+0 points	+0 points

This data suggests that while math journaling and small group discussions really supported students' abilities to choose strong strategies and model them, they still struggle (across the board) to explain their thinking.

What this data does not include are the qualitative observations about students' abilities to converse and debate their thinking, as well as use their rationale to arrive at a consensus. Looking at the sample conversations earlier in this document show that the quality, length, and involvement in student conversations *did* improve significantly over time.

3. What happens to students' math mastery over time?

I did not see positive increases in student data, but I strongly believe that this is tied to the rigor of the assessments versus student skill. The rigor of our math assessments increased greatly over time, and often asked students to solve concrete problems versus ones that include lots of rationale and longer problem solving. (This revealed to me a lack of alignment in my own assessments with what I was trying to accomplish in math journals.) However, I did see that several students (Laura, Araceli,

Yadiel, and Cynthia in particular) demonstrate tremendous growth on their NWEA national percentile scores. This particularly affected students who began as being low in math. Students who began as higher in math did not, as an average, grow as much on this assessment. This discrepancy with my math assessments leads me to think that perhaps the NWEA assessment requires more student thinking than my own assessments. Table 3 shows student mastery scores on unit assessments prior to implementing consistent journals, and after that time. Table 4 shows student percentile score increases on the NWEA assessment.

Policy Recommendations

1. Teacher Level: At least once a week for 20 minutes beginning at the start of the school year, teachers should strategically teach and *practice* skills and mindsets that support reasoning and conversation in math, such as: risk-taking, flexibility, active listening and quality questioning, and perseverance in problem solving.
2. School Level: Beginning at the start of the school year, teachers should implement math journaling and peer-teaching conversation structures at least twice a week to support some of the Common Core Math Practice Standards. These structures should be implemented as early as kindergarten to build a shared set of school mindsets and skills around math reasoning.
3. School Level: As a means of developing teachers towards these peer-teaching conversation structures, each grade level in our Primary Grades Center should participate in the Lesson Study Alliance math program once a semester, such that by the 2016 school year's end, each teacher has had the opportunity to teach a research lesson cycle.
4. Curriculum Level: As demanded by the Common Core State Standards and the PARCC assessment, math curriculums should provide two to three examples of potential discussion or journaling questions to accompany most unit objectives, such that teachers are able to select one that suits the need of their individual classroom.