¡Enséname! Teaching Each Other to Reason through Math in the Second Grade

Lindsey Schmitz
Chicago Public Schools

This action research sought to evaluate the effect of peer teaching structures across subgroups of students differentiated by language and mathematical skill ability. These structures were implemented in an effort to maintain mathematical rigor while building my students' academic language capacity. More specifically, the study investigated peer teaching's influence on mathematical flexibility, reasoning, and math mastery over time. Students across all subgroups grew significantly in the flexibility and efficacy with which they applied strategies in math. While growth in academic vocabulary integration and process writing was not as strong, students with lower math or limited English language abilities showed meaningful qualitative growth in their ability to take risks, share their reasoning, and respond to the thinking of others.

In the final hours of the first week of school, my second-grade classroom was covered with spaghetti and marshmallows. All week, students had broken in the stiff binding of their new math journals and filled clean pages with sketches, labels, and arrows of their plans to create the tallest spaghetti marshmallow tower. They had presented their plans, questioned others' ideas, accepted feedback, and written about how classmates had influenced their final designs. Now, with sticky fingers and their structures littering the tables, students sat down to write their reflections. They did not know it, but this first attempt at learning from the risks of others marked the beginning of what would become an essential part of our math experience, and an enormous shift in my teaching practice: Peer teaching through math journals.

Come Monday, we condensed and repeated the math journaling process with a problem about a mother fish fly who lays ten eggs each day. With Friday's successes behind us, I was shocked to see students staring at blank journal pages, afraid of the space to make a mistake. When it came time to suggest strategies, two high-achieving students essentially had a conversation between themselves, while the rest of the room silently watched, lost. As often happens in these situations, I jumped to put students' work into my own words, delivered a correct answer, and then defeated, asked students to put their journals back into their desks. How could I foster the kind of risk-taking, collaboration, and flexibility that I had seen while building towers? What would it take for even my lowest achieving mathematicians and newest English speakers to be able to confidently share their thinking?

With the action research described in this paper, I investigated the ways that peer teaching through math journaling impacted my English Language learners' ability to express and defend their thinking in math. I sought to determine whether this structure would help students to become more flexible in the math strategies they used, as well as use the academic language of math to defend their reasoning to others.

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 Northwestern Evaluation Association (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 with literacy or elsewhere.

However, we also know that mastery-based judgments of students' abilities in math are limiting. Though my second grade students were achieving high levels of mastery in a rigorous, Common Core-aligned math curriculum, I saw that their ability to express their thinking clearly (with academic vocabulary and clear defense of strategies used) was extremely limited. All but two of my twenty-five students spoke Spanish as their first language. Though they could "do the math," they struggled to put names to the symbols or tools they use, to write about or express their metacognitive processes, or to defend their work against questioning. Likewise, it was 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. In the start of the school year, I saw 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 were 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 standards require so much more of my students. While the Common Core State Standards (CCSS) have been implemented 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 to "make sense of problems and persevere in solving them," "construct viable arguments and critique the reasoning of others," and "model with mathematics." These enduring skills are meant to build procedural fluency, strategic competence, and conceptual understanding. 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. In my PK-8th grade school, 95% of our 959 students identify as Hispanic, and 99% qualify as being from a low-income background. 49% of our population is classified as having limited English proficiency, though nearly all students speak Spanish at home as a first language. 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.

Conceptual Framework

Given the socio-economic, cultural, and linguistic backgrounds of my students, the implications of access to the English language and math achievement are tremendous. According to Moses and Cobb (2001), "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" (p. 5). They describe mathematics as a "gatekeeper and a sieve" that dictates student success, life experiences, and inclusion in society, and claim that students struggling in math lack access to college-level math courses, and subsequently do not have access to our technology-driven economy.

Lisa Delpit (1995), who writes extensively on the intersections of race, language, and academic achievement, presents the idea of a "culture of power" enacted in classrooms. The classroom culture has inherent rules for participating, and these "codes" mirror those of the culture of power in the larger society. Delpit argues this power to be rooted in white, middle-class, English-speaking culture. However, she suggests that when students are explicitly told how to engage in the culture of power, learning what she refers to as rules and codes; they are better able to access it. Within the classroom context, Delpit defines these rules as "linguistic forms, communicative strategies, and presentation of self; that is, ways of talking, ways of writing, ways of dressing, and ways of interacting" (p. 283).

Roberts (2009) translates this idea to math achievement. She argues that access to mathematics classrooms has traditionally been a place where white, middle- or upper class students find success, and are therefore viewed as having "natural" mathematical talent. Roberts further states that the only way for students to pass into this culture of power is with the "framework, tools, words, and ideas that underlie mathematics classrooms" (p. 31). With this in mind, my research sought to identify the way that one teaching strategy, peer-to-peer (or reciprocal) teaching, helps English Language learners develop their academic English proficiency while supporting math content achievement.

Literature Review: The Language of Math

For English Language learners (ELLs) the stakes of strong math achievement are high, and extend far beyond the classroom. Research from the National Center for Education Statistics (NCES) (2015) found that in the 2013-2014 school year, only 62% of English Language learners graduated from high school in four years, as compared to 87% of white students.

One cause for these discrepancies is access to high-level math coursework. A 2016 report by the U.S. Department of Education Office for Civil Rights found that in 2014, English Language learners represented 10% of K-12 students nationwide. However, they represented only 4% of the high school students enrolled in Algebra II, and 1% of the students enrolled in calculus courses. Additionally, only 33% of high schools with high (over 75%) black and Latino populations offer calculus, as compared to 56% of schools with low (less than 25%) black and Latino enrollment (U.S. Department of Education, 2016). Within math classrooms, a study by Abedi, Courtney, Leon, Kao, and Azzam (2006) revealed significant gaps between ELLs and non-ELLs in their "opportunities to learn," stating that most ELLs experience less coverage of math content within a course taught by teachers with less content knowledge, and are surrounded by peers with less prior math knowledge. Additionally, Ballantyne, Sanderman, and Levey (2008) found that only 30% of teachers of ELLs have opportunities for professional development in working with this student population, and only 20% of states require that new teachers receive preparation in working with ELLs.

Furthermore, the National Center for Education Statistics (2011) determined that on the 2011 National Assessment of Education Progress (NAEP), the achievement gap between ELL and non-ELL students was 36 points at the 4th grade level and 44 points at the 8th grade level. When ELLs perform poorly on math assessments, it is difficult to isolate their achievement to lagging content skills or their language abilities. As Goldenberg (2008) explains, “There is no way to know whether ELLs tested in [mathematics in] English score low because of lagging content knowledge and skills, or because of limited English proficiency, or because of other factors that interfere with their test performance—or some combination. Whatever the explanation for these achievement gaps, they bode ill for English learners' future educational and vocational options” (p. 11). Low test scores often result in many ELLs being placed in low-level math courses that focus on basic skills in place of higher-level thinking, or referred for assessment. For example, in a report commissioned by the Massachusetts Department of Elementary and Secondary Education, Hehir, Grindal, and Eidelman (2012) found that Latino English language learners were 70 percent more likely than their native English speaking Latino peers to be referred to special education programs. However, Roberts (2009) states, “language should not be a barrier to high quality mathematics instruction” (p. 30) and the economic and social opportunities it affords.

Roberts (2009) argues as well that this overall misunderstanding of ELLs’ true math abilities results in limited access to meaningful and empowering math experiences. She therefore calls for teachers to help develop enduring English language skills through explicit teaching of math discourse. She states that students must be able to frame their conjectures intelligently, using persuasive language and evidence-based reasoning to present opinions to peers. She also notes the importance of using technical language to share thinking, including both content vocabulary and process-related language. Additionally, Roberts states that students must be able to meaningfully re-voice the ideas of peers in order to actively participate in the conversation as well as monitor one’s own understanding. These are all skills that help students access Delpit’s (1995) “culture of power” beyond the realm of math. Rittenhouse (1998) 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’” (p. 170).

The Math Register

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. They 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 takes on new meaning, like “rational,” or math concepts that can be represented by many words (i.e. add, plus, sum). Students must gain proficiency with syntactical structures like comparatives (“A x B” representing “A times as many as B”) and prepositions (divided by; take one third of). They must be able to comprehend what “logical connectors” such as cause and effect, chronological, or reasoning language mean. All of this has been a major barrier for my students when they attempt to justify their thinking. While their “math” is correct and shows complex thinking, their explanations are vaguely imprecise and are often illogically presented when students lack the connecting words or verbs to describe their thinking process. The result is that my students struggle to learn from other students who are strong mathematicians but who have less developed 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.

Cooperative Learning as Language Instruction

Cooperative learning, in which students of different ability levels have structured opportunities to interact and problem solve, can provide an excellent context in which to develop these mathematical discourse skills. Kang and Pham (1995) state, “Increasing interaction through the use of group work and cooperative learning activities contributes to language development… Such activities provide opportunities for students to use language that is related to the task at hand, expose learners to increased amounts of complex language input, and provide more opportunities for the learners to refine their communication skills through natural second language practice and negotiation of meaning through talk” (p. 9). Additionally, they describe discourse competencies that can be developed with cooperative learning opportunities:

- Heuristic discourse (tell me why): students practice inquiry to explore real world problems
- Imaginative discourse (let’s pretend): students imagine, conjecture, and hypothesize about new situations in which a math strategy or concept can be applied
- Informative (let me tell you): students teach new information to other students
- Representative function (tell how things are: students represent, model, and clarify meaning
- Directive function (do this): students request others to clarify or provide specific information

Considerable research supports the use of peer assisted learning techniques, particularly for English language learners. Much of this research is rooted in Vygotsky’s (1978) theories of constructivism, which states that students more deeply internalize conclusions made in group contexts, 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” (p.85). 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 draw conclusions about mathematical ideas.

Gerena and Keiler (2012) describe a “Peer Enabled Restructured Classroom” in which peer assisted learning is a central strategy and reported that reciprocal teaching that pairs students who are close in language or content ability level as tutor/tutee can be beneficial, if student tutors have recently studied and struggled with—but mastered—the material themselves. Garena and Keiler conducted a study in which student “Teacher Assistant Scholars” (TAS) were paired with ELLs who had failed the New York Regents Exam over the course of a 10th and 11th grade summer school program. ELLs met for 90 minutes of content instruction by a classroom teacher, and then participated in 90 minutes of small group instruction facilitated by the TAs, including group activities, scaffolded learning of new concepts, and assessment of student understanding. Their findings showed that in all categories of the Regents exam, students who participated in the Peer Enabled Restructured Classroom performed as well or better than their English-only counterparts in the program. Likewise, the study found that the TAS benefited from the experience of working with ELLs; of the 15 bilingual TAs who took a final mock Regents exam, all improved their score within a range of +16 to +39 points (of 100).

A powerful study led by Dalton 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 within the math classroom. They found that when students were given time for structured discourse, students ultimately accounted for only 50% of the classroom utterances (a shift from traditional, teacher-heavy math lessons). Additionally, student participation increasingly became evenly distributed over time, indicating that even newcomers and students with lower language skills were meaningfully engaged. Within the IC-based lessons, the students' use of content vocabulary increased from six utterances to 48 utterances within the lesson. Likewise, the measure of "appropriate" (on task, responsive) discourse functions averaged out to be 74% of all conversation. This research supports the idea that IC has a sizable impact on ELL's abilities to co-construct meaning while developing important English language skills. As Dalton and Sison state, "Substantial change occurred in students' use of content lexicon and appropriate responses, revealing changes in students' knowledge base […] Students' use of content lexicon at the levels achieved strongly suggests that, in IC, they were using language for its sociocultural, role-defining, and conceptual functions" (p.14).

While new demands from local 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 English language learners to do this within a student-centered, highly scaffolded, and real-world context.

Methodology

This research was conducted as part of a yearlong action research grant program. The process of action research allowed me to methodically analyze the way peer teaching structures impacted my language learners' abilities to defend their reasoning in our math classroom. Cochran-Smith and Lytle (1993) define action research as "systematic, intentional inquiry by teachers" (p. 5). Gilles, Wilson, and Elias (2010) state that action research requires teachers to develop a research question based on what they observe in the classroom, gather data, and analyze that data in an effort to improve their teaching practice and student outcomes. Action research is well documented as an effective tool for developing teachers and promoting change in schools. Gilles, Wilson, and Elias (2010) found that the process of action research led to wider collaboration and strengthened professional communities among the school faculty.

Additionally, the process strengthened a "renewable professional growth cycle" (p. 96) in which teachers became aware of the power of professional dialogue and were encouraged to continue evaluating classroom challenges through research. Ginns, Heirdsfield, Atweh, and Watters (2001) state that action research can "empower teachers to examine their own beliefs, explore their own understandings of practice, foster critical reflection, and develop decision making capabilities that would enhance their teaching, and help them assume control over their respective situation" (p. 129). As such, action research provided the perfect framework for me to codify my observations about my language learners, develop tools to collect data on their growth, and analyze the results in the hopes of improving my approach with this group of students.

My teaching experience began on the U.S.-Mexico border in Texas, where I worked in an English immersion classroom and experienced similar challenges with helping English language learners become proficient with the math register. After several years in the classroom, I spent two years coaching new teachers in primarily bilingual classrooms throughout Chicago, and began to develop a larger understanding of the high stakes of math education for students of color and students for whom English is not their first language. This research occurred in my third year as a second-grade teacher in a self-contained Chicago Public School classroom. During this time, I participated heavily in the process of lesson study (described below), as well as completed a Master's Degree in Early Childhood Education with bilingual endorsements.

This section outlines the student participants, the instruments and classroom contexts used to collect data, and the procedure by which data were collected and analyzed over the school year.

Participants

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 23 speak Spanish at home as a first language (the latter are not labeled as ELLs because their 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 focused on eight students who serve as a representative sample of the varied language abilities and strength in math content. This cohort of students was selected for several reasons. First, this group represented eight students whose data would be reliable based on their consistent attendance at school all year long. Additionally, focusing on this cross-section of students made intensive data collection (namely frequent video and audio recording and deeper math journal analysis) more feasible. Most importantly, the research question specifically asks how peer teaching will affect language learners, and the groupings of students will help identify for whom the interventions are most effective. I also organized students by math ability, as we know that it is often easy to conflate low math skills with less developed language skills. The composition of these pairs helps ensure we can analyze the impact of interventions on different levels of language learners effectively.

Students were organized based on several qualitative observations during math instruction, including their flexibility in applying a variety of math strategies to complex problems, the extent to which their strategies led to accurate work, their ability to clearly communicate their approach to others using the math register, and their ability to engage in conversation with others about different approaches.

Table 1
Student Subgroups[1]

	Developing English Language	High English Language Development
High Math Abilities	Araceli Yadiel	David Alexia
Developing Math Abilities	Cynthia Laura	Mayeli José

Instruments

Data were collected using an assortment of methods, primarily within the context of math journaling. Students opened the lesson with a math journal prompt about three days a week. I began this process while engaging in the Japanese practice of *Jugyokenkyu*, or lesson study. Several years ago, my school's principal and several members of our math team visited Japan to observe math instruction and engage in the lesson study process with teachers there. Since that time, kindergarten through third grade teachers engage in the research and teaching process twice a year. At the time of this research, I taught the "research unit and lesson" that our team of teachers planned together, and presented it before many of our staff members and members of the Chicago Lesson Study Alliance. This experience led me to implement the lesson structure and best practices in my own classroom throughout the school year.

Lesson study brings teachers together to develop a research focus (such as appropriate use of mathematical tools), engage in research of the underlying content and best teaching practices, plan a lesson together, and observe students engaging in the lesson. According to Doig and Groves (2011), a typical Japanese lesson like those used in lesson study begins with a single, thought-provoking question or problem statement, or *hatsumon.* Students are then given time to work individually or in groups on the problem while the teacher carefully notes which students are using specific strategies. During this crucial time, the teacher strategically plans how she will lead students to present their work in a way that puts the ownership on students, facilitates peer-to-peer teaching, and leads to achieving key lesson goals. Takahashi (2006) states, "Because the goal of the structured problem-solving approach is to develop students' understanding of mathematical concepts and skills, a teacher is expected to facilitate mathematical discussion for students to achieve this goal" (p. 6).

In my classroom, I implemented the lesson study structure about three days a week. Each of these lessons began with a challenging math journal that allowed for multiple paths to a solution. Students use whatever strategies and manipulatives they choose to solve math problems 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. I also asked students to self-assess before and after the group time to quantify how well they understand. This tool helped students

[1] Names of all students have been changed.

to stay metacognitive, while giving the teacher a read on the efficacy of this structure. Most student work and video samples were collected during students' presentations of strategies. The following instruments were used to collect student data:

Student math journals

I reviewed samples of journals across the class weekly, but took samples of journals from the four subgroups of students about every three weeks. I used a rubric (below) to rate students' growth across five domains: Strategy Use, Modeling, Vocabulary Use, Process Writing, and Reflection. The strategy use and modeling strands revealed information relevant to the research question *What happens to students' flexibility in the strategies they use?* The vocabulary use, process writing, and reflection strands help illuminate growth towards the final question: *What happens to students' ability to defend their reasoning mathematically?*

Data collected was organized in three ways:

- Individual students' 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.

Figure 1. *Math Journal and Conversation Rubric: Teacher Version*

		4 points	3 points	2 points	1 point
Flexibility	**Strategy Use**	• Clearly articulated and described strategy • Told WHY strategy was more effective and efficient	• Clearly articulated strategy • Told why strategy was more effective OR efficient	• Strategy articulated but may be unclear • Generally tell why they chose the strategy	• No articulated strategy (may be list of steps) • Did not tell why strategy was chosen
	Modeling	• References work while explaining clear steps • Explains steps with detail and rationale	• References work sometimes • Clearly articulates the steps of their problem	• Attempts to show work to peers but may not reference it. • Articulates at least half of steps	• Does not share steps or steps are very unclear
Defense of Reasoning	**Vocabulary**	• Uses technical vocabulary consistently, correctly, and often • Language is precise	• Uses technical vocabulary at several points • Language is precise	• Uses technical vocabulary at one or two points • Language may not be precise	• Uses no technical vocabulary • Language is imprecise and confusing.
	Process Language	• Student is conscious of their "teaching voice" in explaining their process. • Student uses transition words and writing is sequential. • Student explains both the "why" and the "how"	• Student uses transition words and explanation is sequential. • Student clearly explains how they solve their problem and name the strategy.	• Explanation is sequential. • Student somewhat clearly explains how they solve their problem OR the strategy they use.	• Explanation is not sequential. • Student does not explain how they solve their problem or the strategy they use.
	Reflections and Comparisons	• Compares strategy to that of peer with clear connections • Clearly articulate why one strategy is more effective	• Compares strategy to that of peer • Clearly articulate why one strategy is more effective	• May attempt to compare, defend, or show preference for one strategy over another, but does not provide rationale.	• Does not attempt to compare, defend, or show preference for one strategy over another

Video recordings

As mentioned earlier, students first met in heterogeneous small groups of four students to present their strategies. One of these groups was strategically organized to include one student from each of my four focus subgroups: Laura, Anthony, Jose and Alexia (Anthony was substituted for Araceli early in the research, as she became extremely shy around any recording device and her contributions were not reliable). After small group conversations, two or three students were strategically chosen to present their work to the class. Video recordings were made to capture students' presentation of their strategies, as well as the group conversation that followed. I recorded one whole class conversation (about eight minutes) and one conversation from the small group mentioned above (about five minutes) about once a week for four months. This added up to over 200 minutes of video that allowed me to review student language and engagement during the conversations. I transcribed small group conversations about once every three weeks, and used the Math Journal and Conversation Rubric to assess student flexibility and reasoning. While I did not transcribe whole group conversations, as not every student in the class participated every time, I assessed them about once every three weeks using the same rubric to draw out trends and areas for whole class growth.

The video samples revealed many things: student engagement, the strength of student questioning/discourse, students' abilities to explain their modeling and thinking, etc. In particular, I observed for students' vocabulary use, process language, and comparisons of strategies, as these provided evidence towards the research question *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 (see below). 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)

Figure 2. *Math Journal Conversation Rubric: Student Version*

	1 point	2 points	3 points
Sharing Time and Ideas	• Not everyone got to share. • Some people talked more or less than others.	• Every person got to share. • Some people talked more or less than others.	• Every person got to share. • Each person got about equal time to share.
Listening	• Our group did not have eyes on the speaker. • Our group did not show active listening. • We didn't help people stay focused.	• At least 2 people had eyes on the speaker. • At least 2 people's bodies showed active listening. • If someone talked out of turn, we helped them stop.	• All eyes were on the speaker. • Our bodies showed active listening (lean in, nod) • Only one person talked at a time.
Questioning	• None of our questions helped others to fix their answers. • None of our questions were ones that helped when we were confused. • We already knew the answers to most questions.	• Most of our questions helped others to fix their answers. • Most questions were ones that helped when we were confused. • We didn't know the answers to most questions.	• Ask questions that help others fix their answers. • Ask questions when you are really confused. • Don't ask questions you know the answer to!

Student performance tasks

I administered three performance tasks (in September, January and March) asking students to respond to an open-ended problem requiring flexibility and innovation. For example, on March 13th, students solved the following problem:

> When Ms. Bell and her sister were little, they would always fight about who got the most candy or toys. Their mom always had to count things out for them to calm them down. One day, their mom had 32 M&M's. She wanted to keep half of them to eat for herself and then evenly split the other half between Ms. Bell and her sister.
>
> a) How many M&M's did Ms. Bell's mom get to eat?
> b) How many M&M's Ms. Bell and her sister each get?

Students responded 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 (Figure 1).

Teacher journal

I reflected in a teacher journal about once a week. Quotes, observations, and data recorded in this journal gave insight as to how well new structures or approaches were working and in what areas I needed to continue focusing.

While I collected data from all these sources, the findings in this paper primarily focus on data from student journals. Journals were the most reliable and consistent measure of students' abilities to be flexible in their math strategy use and defend their reasoning. First, journal writing was implemented most frequently (about three times a week), providing dozens of entries per child to potentially be analyzed. Unlike performance tasks, which were administered only three times a year, they provided a much more reliable picture of student growth in flexibility and reasoning over time. Finally, math journals were the only tool that measured both components of flexibility (strategy use and modeling) and all three components of reasoning (vocabulary, process language, and reflection/comparison). This was not true of performance tasks (in which students did not get to compare their work to that of a peer) or student assessments (which only measured student mastery of discreet math skills).

This paper will also examine data from video recordings and transcriptions of student conversations. These data also provided insight into student flexibility and defense of reasoning. As opposed to journals, which measured the same skills on paper, video transcriptions provided important insight as to students' oral flexibility and reasoning. Focusing on these two data points illuminated important differences in students' written versus oral language development, which will be discussed in the findings below.

Findings

Both math journal and video transcription data revealed that students became more flexible in their math strategy use and improved their ability to defend their reasoning.

Math Journals

Student flexibility. I measured students' flexibility quantitatively through their ability to choose meaningful strategies while problem solving in their journals and working performance tasks, and through their abilities to show meaningful comprehension through strong modeling (as measured by the strategy use and modeling strands of the journaling rubric in Figure 1). 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 were not only able to select a meaningful strategy, but could also apply it with deep thinking.

Qualitatively, I saw tremendous areas of progress in students' abilities to identify effective and efficient problem-solving strategies. In the beginning of the school year, students did very little problem analysis to identify the tool that would most help them. Some students simply stuck to strategies that were "fun," such as using coin manipulatives or counters. Others consistently defaulted to a strategy that had worked once for them before, such as drawing a number line. By the end of the school year, I saw students not only choosing appropriate strategies, but also able to articulate their rationale clearly. For instance, Alondra (not part of the subgroups) wrote about her use of a number line, "I did it because I need to add and I can hop by big numbers first and small numbers also and it's faster like this." Her labeling of a number line read "ten pairs" and demonstrated understanding of how she could add larger "chunks" of 50, and then "hop" (count on) by groups of ten, and then one, using ten pairs throughout. Further evidence of this impact is found in student conversation. Many students moved from commenting on other's work with vague statements like, "Why did you do it that way?" to precise and thought-pushing questions like, "Don't you think it would be faster to use a number line than to draw pictures of coins and add them all up?"

Student ability to defend reasoning. I measured students' reasoning and defense of their strategies through their vocabulary use, reflections/comparisons and "process writing," or written explanations of how they used their chosen strategy to solve the problem.

Over time, students' process writing improved the least, along with vocabulary use, of any rubric area (+.5 points on the rubric). However, students did improve 1.1 points on average in their abilities to reflect. Students who grew the most in their ability to explain their reasoning overall (as measured by their combined growth in vocabulary use, process writing, and reflection) were the students with both high language and high math abilities, followed by students with high language and developing math skills. This suggests that journaling did *not* positively impact students with less developed language to express their work in writing.

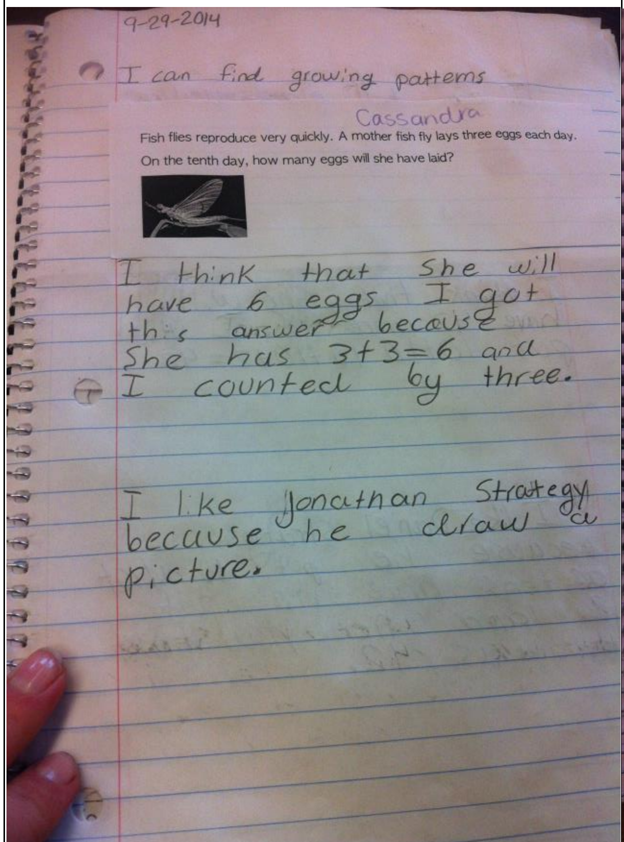
However, I did see great improvements based on the data gleaned from video conversations in the area of vocabulary. This was particularly true for students who were still developing in math. While this data seems to contradict the written vocabulary data, it may be more authentic, as writing presents additional barriers for students who need more time, are frustrated by spelling, or are overly focused on grammar rather than content. 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.

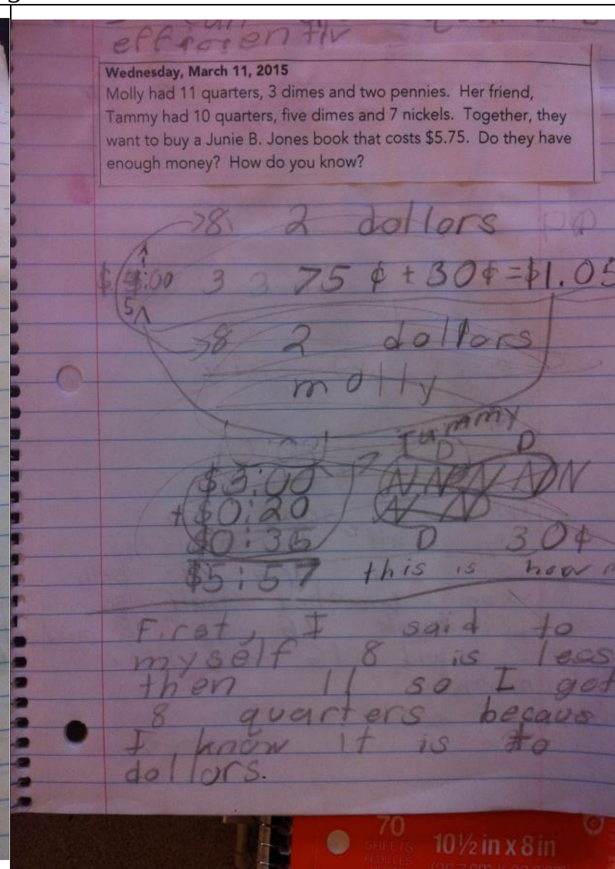
While trends can be gathered for the class as a whole, each of the four subgroups of students grew differently in their abilities to demonstrate flexibility and defend their reasoning (see Appendix A for detailed data on subgroup students' journaling scores).

Students with developing math and English language abilities (Laura and Cynthia)

Laura and Cynthia differed significantly in their overall growth, with Laura growing 6 points (of twenty possible) and Cynthia growing only 1 point overall. Both girls grew most in their math flexibility (2 of 4 points growth in modeling), perhaps because they were very reluctant to even attempt problems initially and progressed to be able to present strong problem-solving on paper, as shown in the images of Cynthia's journals below. However, these students did not show any growth in their abilities to defend their reasoning. Neither student showed growth in process writing or vocabulary use, and ended the year still averaging one point on the rubric in both areas.

September Journal	**March Journal**
Cynthia's journal shows high growth in the areas of modeling, but her process writing is still unclear.	

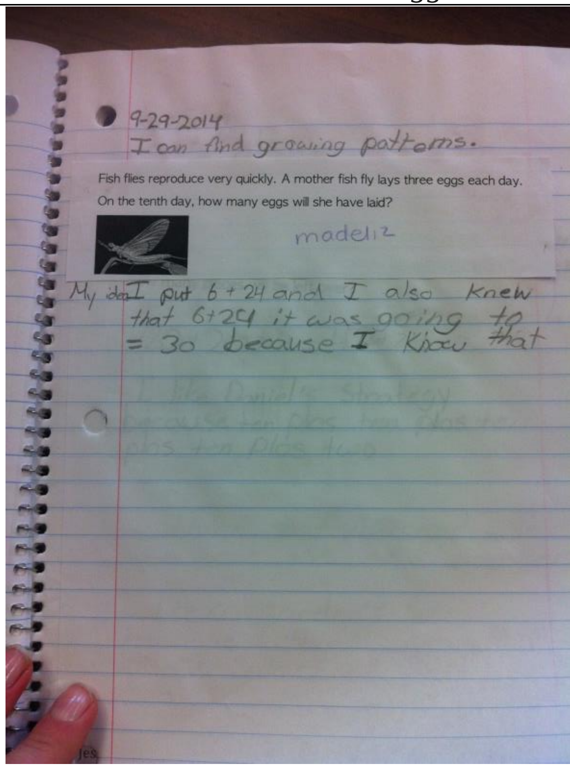
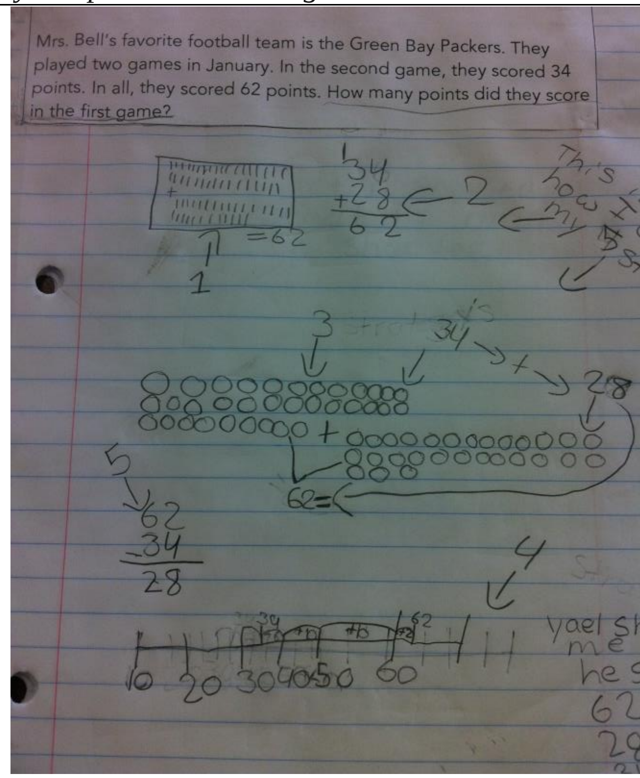




Students with developing math and high English language abilities (Mayeli and Jose)

Like Laura and Cynthia, who also have developing math skills, this subgroup of students improved the most in modeling. They, too, showed very little growth in vocabulary use, writing, and reflection. This pair also showed large discrepancies; Jose grew a significant amount overall (7 points), while Mayeli only grew 3. However, their final rubric scores (10 and 12, respectively) were very similar. Both students ended the year with very low NWEA scores and among the lowest NWEA percentile growth in the class.

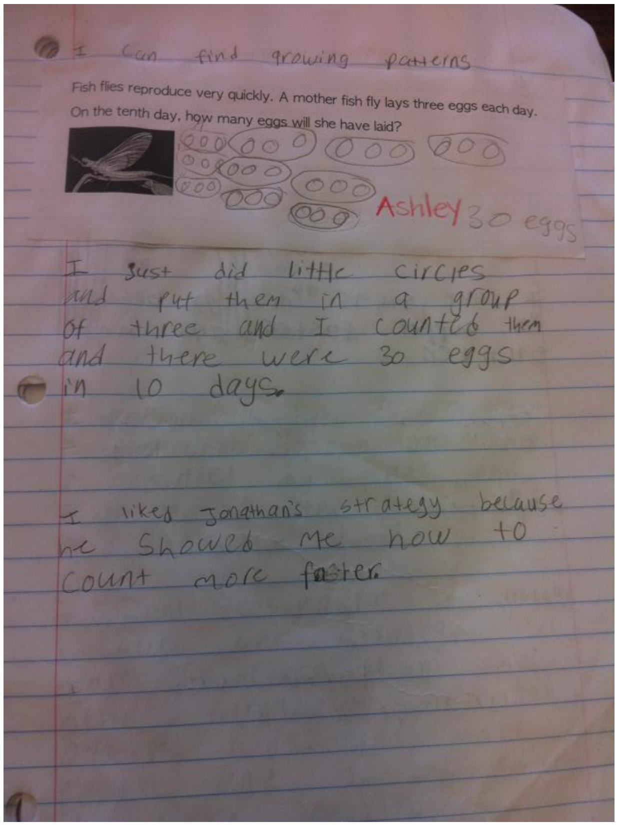
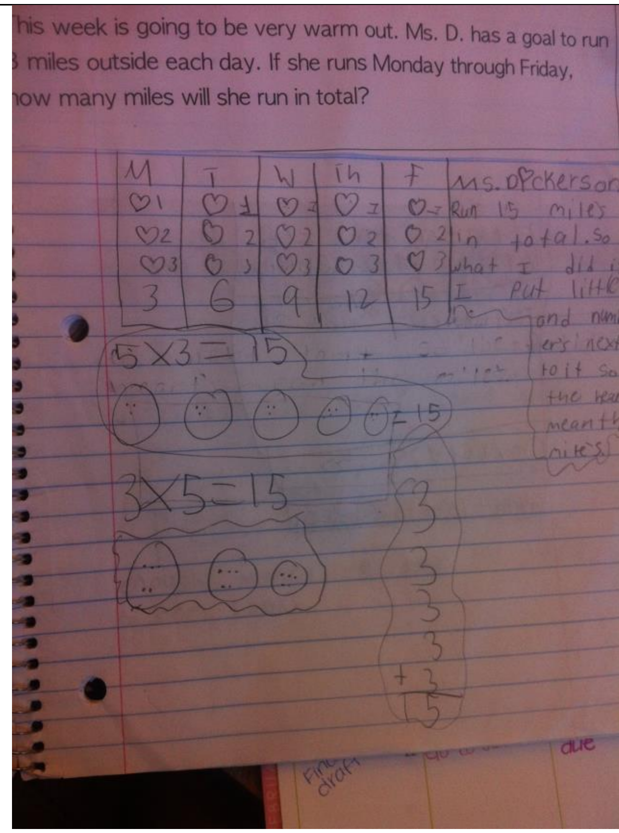
Like most students in the class, Mayeli and Jose grew most in their ability to flexibly apply strategies (growing 1 point in strategy use and 2 points in modeling each), and least in their ability to defend their reasoning. While Jose showed 1 to 2 points of growth in each area of reasoning, Mayeli did not grow in any of the areas related to reasoning.

<table>
<tr><th>September Journal</th><th>March Journal</th></tr>
<tr><td colspan="2">Like Cynthia, Mayeli grew much more confident and accurate in her modeling, but still struggled to convey her process in writing.</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Students with high math and developing English language abilities (Araceli and Yadiel)

This subset of students had the most divergence. To begin, Araceli showed fairly significant growth overall (+6 points) while Yadiel only grew 1 point. In fact, Yadiel showed the least overall growth of any student with the journals, only demonstrating 1 point overall of growth in the area of strategy use. He had the lowest end overall score (10 points of 20) of any student in the four subgroups. However, despite low growth in math journaling, both students demonstrated very high growth in NWEA percentile scores.

Like most students, they grew most overall in their flexibility: Araceli grew most in modeling, while Yadiel grew most in strategy use. Araceli was one of only three students who grew in all areas in her journals. It is worth noting that she also showed consistent growth in vocabulary use, process writing, and reflection writing—something that was not true for most of the students.

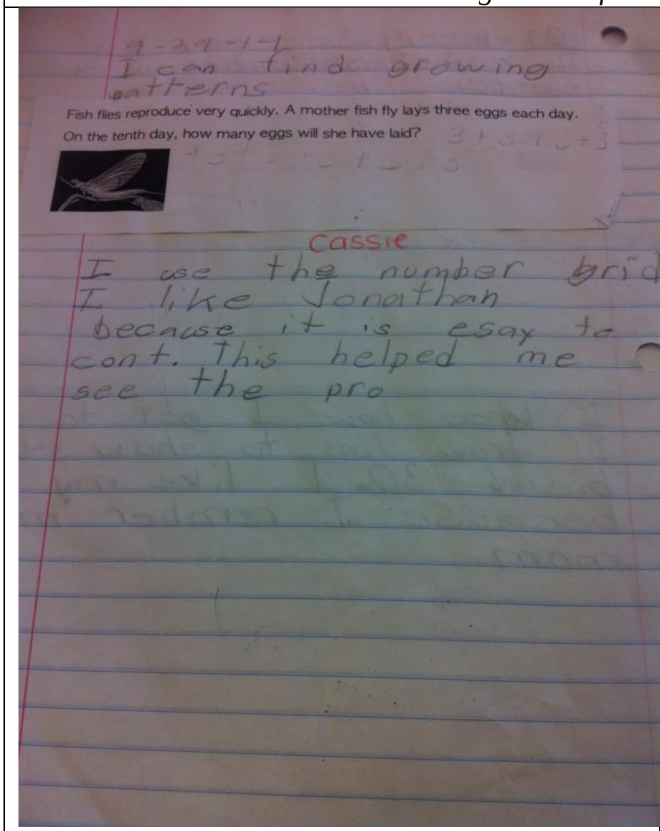
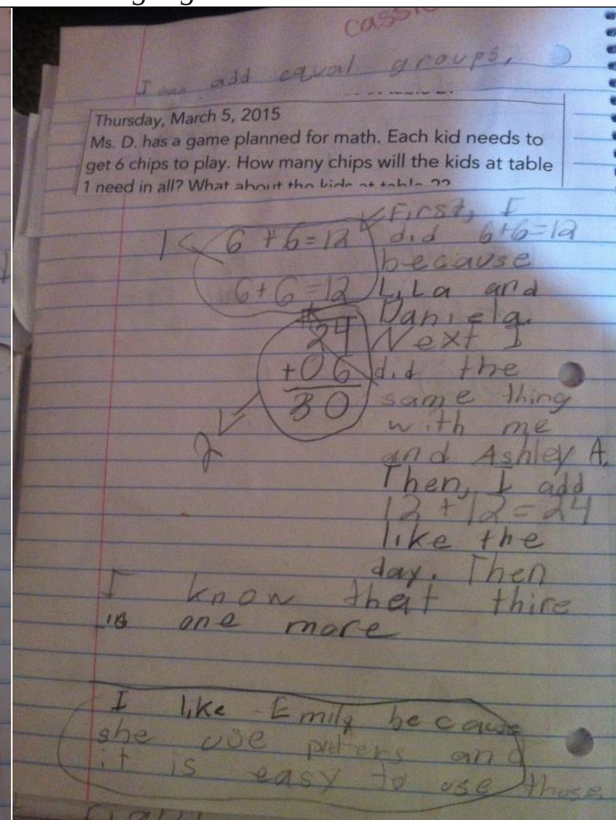
<table>
<tr><th>September Journal</th><th>March Journal</th></tr>
<tr><td colspan="2">Araceli not only showed strong gains in math content knowledge, as measured by NWEA, but also grew in every other area of the rubric. No other student did this.</td></tr>
<tr><td>
</td>
<td>
</td></tr>
</table>

Students with high math and high English language abilities (David and Alexia)

Though these students represent those with the most developed English language and math skills, their overall baseline scores were not the highest in the class. Both students showed very different levels of growth: David only grew 2 points overall, while Alexia grew 13 points and had a perfect overall rubric score at the end of the research.

Both students had perfect overall rubric scores in areas measuring flexibility (strategy use and modeling). Alexia grew more in her modeling (3 points of 4) than any other student in the subgroups. She was also one of the only students who grew as consistently in her ability to defend her reasoning as she did in her flexibility, growing an average 3 points each in vocabulary use, process writing and reflection/comparison.

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. He only grew 2 rubric points (of 20 possible) overall, and did not grow at all in any areas related to defending reasoning.

<table>
<tr><th>September Journal</th><th>March Journal</th></tr>
<tr><td colspan="2">Alexia’s high engagement in the math journaling process supported her already strong levels of math and language.</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Math Conversations

In addition to analyzing math journals, video transcriptions of small group conversations provided important insight into the subgroup students’ flexibility with math strategies and their abilities to defend reasoning. As mentioned above, I focused my video recordings on a small group of four students representing each of the four subgroups used for data analysis. I did not transcribe whole class video data for this study, only data for the subgroup of students that I observed over time. As different groups of students engaged in each whole-class conversation, it felt difficult to measure growth reliably over time. I did informally assess whole-class conversations on our Math Journal and Conversation Rubric to identify whole-class trends and areas to target for growth.

However, whole class data revealed several trends. First, I noted that students with strong math skills (regardless of language development) participated the most in whole group conversations. Likewise, this group of students was most likely to persevere through the end of a whole group discussion. Additionally, I found that students’ abilities to explain their math reasoning (the equivalent of what we scored as process writing in their journals) was significantly stronger when done orally than when writing in journals. Finally, reviewing video of whole group conversations allowed me to pay close attention to students struggling with misconceptions about the content by observing how their thinking did (or did not) change during the course of these conversations. I frequently noticed that students who began the journaling and conversation process with knowledge gaps or misconceptions did *not* resolve them while listening to the strategies presented by their peers.

In the small group conversations, students shared their approach to problem solving while the three other students asked questions or shared reflections and comparisons. Video recordings of small group conversations revealed much more growth in the area of defense of reasoning than was captured in the journal rubrics, though the results varied by student studied.

Table 2. *Subgroup Journal and Conversation Comparison*[2]

	Laura (Developing Language, Developing Math)		**Jose (High Language, Developing Math)**		**Anthony (Developing language, High Math)**		**Alexia (High Language, High Math)**	
	Written	Oral	Written	Oral	Written	Oral	Written	Oral
Vocabulary Use	+0	+2	+2	+3		+1	+3	+1
Process (Writing or Explanation)	+0	+0	+1	+0		+0	+3	+0
Reflection	+2	+2	+1	+2		+3	+3	+1

This table isolates students from the subgroup used for studying oral reasoning in math conversations, as measured by vocabulary use, process explanation (the equivalent of process writing in math journals) and reflection/comparison. The table compares an individual student's abilities to demonstrate reasoning through writing in their math journals (as shown in Appendix A) with their abilities to do so orally in the small-group setting. All growth is shown as achieved points out of a possible four on our Math Journal and Conversation Rubric.

Laura (developing math, developing language). Laura grew significantly (2 points growth of 4) in her ability to explain her strategies using content vocabulary, though it remained an area of challenge for her. However, Laura's ability to reflect on her own strategies and those of others improved significantly (2 point growth). 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 Laura was able to reflect on her own strategy and compare it to that of a peer, it still shows that vocabulary usage was behind that of her peers.

[2] This subgroup originally started as Laura, Jose, Alexia and Araceli (all part of the original eight focus students). I substituted Anthony for Araceli shortly after I began recording small group conversations because Araceli became extremely camera shy and I therefore could not collect reliable data. As such, I did not assess Anthony's math journal as frequently as I did for the other students in the subgroup and do not have initial data to which I can compare his final data.

Jose (developing math, high language). Jose grew significantly in the area of vocabulary use within his math conversations. 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.*" Jose grew from 1 to 3 points on the rubric in vocabulary use from December to February. Most notably, he grew in his ability to show deep comprehension in his reflections and questions. Initially, his questions 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 10. 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 (developing language, high math). Anthony 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 are for.*" In March, while explaining his approach to a problem involving tiling a shape to find the area, he said, "*I looked for curved edges, and some worked. Then, I tried to put some more curved edges and it didn't work. Then, I tried triangles like this. Then I kind of connected them together. Right here it worked well but right here it didn't.*" Anthony's response includes more content vocabulary (*curved, edge, tiled, triangles*) as well as uses process language (*then)* and a clear sequence to explain his approach.

Alexia (high math, high language). Alexia began the small group conversation process with very high oral language and math abilities. As a result she often engaged less in these conversations because her strategies were much more complex than those expressed by the other students (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 had very consistently high scores in all areas of the conversation rubric. Her strategy from February illuminates some major differences in the levels 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 subgroup 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 • Six exchanges • Three 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 tiled 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. 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.

While I primarily focused on student journals and transcriptions of small group conversations, I also collected data using student performance tasks and math mastery assessments.

Student Performance Tasks

Overall, students did not grow as much in their flexibility and reasoning on performance tasks as they demonstrated through journaling and small group conversations. Appendix B shows student growth data for flexibility and reasoning across the three performance tasks administered in September, January, and March. These were measured by the same rubric as math journals with the exception of reflection, as the tasks were completed independently.

Students' baseline scores were similar to those in their math journaling (no student averaged a difference of more than 3 points between their journal and performance task baseline scores). However, their growth on performance tasks was, on average, significantly less. Students in the subgroups grew an average of 4.75 points on the math journals, but only grew an average of 2.4 points on the performance tasks.

As in the math journals, modeling continued to be a slightly higher area of growth than most other areas (.75 points of four as compared to .5 points of growth in both strategy use and process writing). Unlike the math journals, students grew more in vocabulary use than they did in other areas like process writing and strategy use (also .75 points of four).

It is difficult to aggregate trends within the subgroups, as it was for math journals, because there are often discrepancies within subgroups. For instance, Alexia grew an overall 7 (of 16) points over time on her performance tasks, while her high-language high-math skills counterpart David did not show any growth. Additionally, growth was not consistent for individual students between the math journals and the performance tasks. For instance, Araceli grew 6 points (of 20, or the equivalent of 30%) on her math journals, but showed negative one point (of 16, or the equivalent of -6%) on her performance tasks.

Discussion and Analysis

Phase One: Launching Journaling and Focusing on Flexibility (September-January)

Research began near the end of September, through the structures of math journaling/lesson study described above. Much of September was used to teach the procedures for math journaling, including setting up the journal, expectations for independent work time, access to classroom manipulatives, etc. Additionally, I implemented several mini-lessons meant to encourage a culture of risk-taking and learning from mistakes in the hopes that students would gain comfort doing so in their journaling. During this time, students practiced respectfully listening to and responding to others' strategies in extremely basic ways, using provided language stems such as "I agree with ____ because" or "Can you tell me more about why you chose that strategy?" Math journal conversations lasted about ten minutes at this time, and I began collecting video of student conversation about once every two weeks. I also administered the first performance task. However, September and October really served as a time to collect baseline data around the skills all my students were entering second grade with.

By November and December, students had become comfortable with journaling and discussion protocols and were likewise gaining flexibility in their journaling approach as well as stamina in the length of conversation. In December, I decided to begin conversations by creating smaller groups of students organized heterogeneously by both math ability and English language development levels. We crafted expectations for sharing, responding to, and synthesizing strategies, and students used the whole class discussion rubric (Figure 2) to assess their conversation. After these short discussions, the class would come back as a whole and I would strategically ask one or two students from each group to share their learning (with significantly less whole class discussion afterward). This structure engaged nearly all students and allowed me to collect conversation data from a consistent group of students over time.

In January, I began to focus significantly on student conversation. While students understood the behavioral and engagement expectations involved, conversations were still highly teacher-facilitated. I hoped to help students engage more deeply so that they could fully develop and demonstrate flexibility in the strategies they used and clearly share their reasoning with others. About once a week, students and I analyzed YouTube and other online videos of high-performing classrooms' math conversations, identifying the markers of quality math talk we heard. We used these criteria to create a math conversation rubric (Figure 2), which my students then utilized to self-assess the videos of our whole-class conversations. These self-assessments became the basis of my teaching points. I spent about the first five minutes of math class focusing on student conversation and modeling an explicit habit or skill, such as rephrasing a peer's comment, or asking specific and clarifying questions. Students frequently observed their peers in a "fishbowl conversation," during which they physically circled around a small group to observe the discussion, note exemplary behaviors, and then debrief what they observed. I also administered the second of our three performance tasks in January.

As meaningful engagement in the math discussions increased, I found that some students could not stay engaged throughout an entire conversation. Students with lower stamina, like Mayeli, disengaged early on, often leaving the high-performing students, like David, to their own conversation. This disconnect most negatively affected students with the lowest language proficiency and the lowest performing in math, who could not keep up with the increasingly long conversations.

Around February, I began looking critically at the conversation data and realized that students were *not* showing the growth I had hoped they would show. While they were using their journals to demonstrate higher levels of flexibility through the strategies they chose and the modeling they did, I did not see tangible growth towards their ability to defend their reasoning verbally. My note of January 7th reads:

> 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. 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. 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 now see that they not only always have some kind of solution, but also can generally describe their thought process. While they certainly don't meet expectations on the rubric I developed, they do show the most growth.

Phase Two: Focusing on Reasoning (February-May)

The recognition of where my students needed more help 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 taken in the months of December and January included:

- Systematically breaking down the smaller skills embedded in process writing, vocabulary use, and reflection into teachable objectives, such as integrating transition words (i.e. "this shows me," "this is how I knew") and sequencing language (i.e. "next," "finally") when describing a process; using vocabulary to add specificity to descriptions; and revising writing to show, rather than tell, process
- Integrating writing mini-lessons at the beginning of math lessons 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 visuals and everyday objects, 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 in the three individual target areas. As one representative example, Cynthia grew significantly in her ability to explain her problem-solving process. In September, her explanation read, "*I got this answer because 3 + 3 = 6 and I counted by 3*." This process was not accompanied by any modeling or labeling of steps. In March, she wrote, "*First, I said to myself '8 is less than 11' so I got 8 quarters because I know it is two dollars*" (she continued this metacognitive process in depth on the next page to explain her detailed modeling).

During this time, I also thought 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. While I had already been collecting video of small group conversations, in February I decided to shift my focus from the kind of math reasoning being done in each group to the *quality* of the conversation. To understand how students were conversing, I collected video about once every two weeks on the subgroup of students (Laura, Anthony, Jose and Alexia) who represented each of the four subgroups. I continued these video recordings bi-weekly through March, and was able to transcribe conversations to collect more qualitative data.

The Impact of Math Journals

This research demonstrated that while the math journaling process did have a positive impact on the subgroup students' flexibility in math, it did not have as strong an impact on their ability to share their reasoning.

Subgroup students grew significantly more in the area of modeling (corresponding to math flexibility) than in any other area (a total of 15 points as a group as compared to the 8 points grown in strategy use and reflection and the 4 points grown in vocabulary use and process writing.) This growth was also more consistent from student to student than other areas of the math journaling rubric; all students, with the exception of Yadiel, showed at least 2 points of growth. Growth in the area of strategy use (also corresponding to math flexibility) was also consistent for nearly all students. They each grew one point, with the exception of Laura (who grew two) and Cynthia (who did not show growth). Strategy use growth seemed to occur in tandem with growth in modeling. That is, students typically grew a similar amount in modeling as they did in strategy use, and had similar final scores. For instance, Laura grew two points in both modeling and flexibility, for a final rubric score of four points in both areas.

While all students in the subgroups grew nearly equally in the areas of modeling and strategy use, I was most pleased to see growth in these areas for students with developing math skills (Cynthia, Laura, Mayeli and Jose). Each of these students had baseline scores of 1 or 2 points in both areas of the rubric, but was still able to show as much growth as his or her peers with better developed math skills. Qualitatively, I saw that these students gained confidence in identifying strategies that made sense, given the problem, and breaking down the steps of using that strategy enough to model it concretely.

Despite its positive impact on math flexibility, the math journaling process did not lead students to as much growth in their ability to express their reasoning (as measured by vocabulary use, process writing, and reflection). Students' growth in these areas was both less than it was for the areas of modeling and strategy use, and was also less consistent across students. For instance, Alexia grew 3 points in her reflection while David did not grow at all (both students are in the high math, high language subgroup).

I believe the high growth in areas related to flexibility and low growth related to areas of reasoning occurred for several reasons. First, modeling and strategy use are the least language-dependent components of the math journaling process and rubric, as opposed to vocabulary use, process writing, and reflection. Students with developing English language skills (Laura and Araceli) and high language skills alike (Alexi and David) were able to receive 4 points of 4 on the journaling rubric for modeling and strategy use. The amount of language required by each part of the journaling process also highly affected student engagement and motivation. I saw nearly 100% student engagement among the whole class during the problem-solving portion of journal writing. Students at all levels of English language development and math abilities were excited to use all of the allotted time to attempt a strategy. In fact, students who finished early were often anxious to test out a second or third strategy, or to check their models for clarity. However, I frequently had to encourage students of all language and math abilities to add more to their process writing or reflections. During each lesson, there were at least one or two students in the classroom who would not begin the writing portion without teacher encouragement. On the whole, students were significantly less invested in revising their process writing and reflection.

This may have been because the math journal process, as used in my classroom, was designed to motivate students to strengthen their strategy use and modeling skills but not necessarily improve their writing or reflection. I strategically chose individual students to present to the class; some were chosen because their strategies were either effective *or* efficient but not both, others because we could learn from their modeling (as either an exemplar or non-exemplar), and still others because their strategies illuminated key points of the lesson. While I did not intend this to be the case, students internalized that I chose individuals based on their strategy choice and modeling abilities. Therefore, students—regardless of language or math abilities—were deeply motivated to present their strategies to the class, and therefore looked to integrate new and more challenging problem-solving strategies in their journals. They were also invested in presenting strategies that their peers would find both *effective* and *efficient*, so they became increasingly precise in their modeling. I do not believe they associated the *reasoning-related* areas of math journaling as closely as they did the *flexibility-related* ones with the concept of strong math thinking.

Math strategy use and modeling were also the easiest components of the math journals to explicitly teach and use to provide feedback to students. Students observed me thinking aloud about the strategies I used multiple times within one lesson. Likewise, they observed me creating precise and meaningful models of problem solving every day, even in lessons when the math journaling structure was not being used. Conversely, I explicitly taught the integration of vocabulary, process writing skills, and reflection writing much less frequently. Roberts (2009) calls for teachers to explicitly teach the structures of mathematical discourse both orally and in writing. Likewise, Kang and Pham (1995) state that language and content should be taught in an “intertwined” way that links academic math language to concrete application of strategies. Upon reflection, I may have separated lessons that taught explicit discourse and language structures from lessons that taught content. I should have prioritized instruction that supported written reasoning as explicitly as I did strategy selection and modeling.

Finally, when students presented their strategies and models or observed the work of others, they received immediate feedback on the effectiveness and efficiency of the strategy they chose and the clarity of their modeling. However, I was the only person to give feedback on their vocabulary use, process writing, and reflection in the journals. Additionally, this feedback occurred less frequently and was typically provided as written notes within the journals and not as part of an in-person conversation.

Whole Class and Small Group Conversations

Despite the valuable information they shared, math journal data did not reflect 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 amongst the subgroup studied *did* improve significantly over time. First, small group conversation recordings revealed that involvement and engagement was significantly higher in those than in whole group conversations. In regards to the whole class, students who struggled to understand the math reasoning of others “dropped out” of the conversation as the presenter’s math reasoning became more complex and they were unable to ask clarifying questions or comment on the strategies being presented. This did not seem to happen to students with strong math but developing language skills, suggesting that a strong math foundation helped students compensate for language challenges while listening or responding to the work of others. However, small group conversations held all students accountable for engaging. I was able to circulate the room and coach students to “invite missing voices back in” through language stems like, “We haven’t heard your opinion yet, _____.”

Likewise, I believe that the small group context supported students considered to have developing math skills, as they were more likely to ask clarifying questions of the presenting student or acknowledge misconceptions in their own work in front of three peers than in front of the whole class. One example is in the March 12 conversation excerpt above, when Laura took a risk to acknowledge her misunderstanding, stating, “I kept trying with the triangles and it kind of worked. Right here it worked well but right here it didn’t.” Roberts (2009) states that one of the best ways for students to strengthen math skills is to be able to re-voice the ideas of others while monitoring their own thinking. There were significantly more opportunities for *all* students to engage in this process during small group conversations than during individual journaling or whole group conversations. Kang and Pham (1995) call for students to use multiple kinds of discourse during math conversations. During whole group conversations, the students who did participate tended to engage in *informative* (explaining) and *representative* (modeling) discourse. However, during small group conversations, they also had opportunities to engage in *directive* (asking their small group to try a new approach) and *imaginative* (considering hypotheses about strategies) discourse.

Additionally, students revealed significantly stronger oral reasoning while conversing in the small groups than the written reasoning they displayed (as measured by process writing, vocabulary and reflection) in their journals. I believe this was due to two things. First, students could rely on the modeling they had done in their journals to support their process explanations. Students in small groups huddled around these models while the presenting student described their strategies. During this time, I saw students use sequential language (“First I…”, “The next step was to…”), precise verbs, and more accurate vocabulary. A second cause for improved oral reasoning may have been a perceived higher level of accountability, knowing that their peers (or I) would ask them to clarify orally if their process explanations were unclear (something that did not occur within the written journals). This is supported by the research of Dalton and Sison (1995), who found that structured discourse (like the protocol introduced for small group conversations) led to significantly more student utterances of academic language and more even participation.

Finally, I believe small group conversations had a strong impact on students’ flexibility in the strategies they used. While reviewing recordings of small group conversations, I noticed that students were increasingly able to move towards a group consensus about which strategy was most effective or efficient. There is evidence of this in the March 12 conversation, when Jose and Alexia wrap up the conversation with:

> Alexia: We could put these squares into an X, and put one square here, one there, and another over there.
> Jose: That's the (strategy)—that's what we should do.

When students were limited to explaining their strategy only within their own journal, or listening to the strategies of others but not necessarily engaging with the discussion, they had fewer opportunities to refine their thinking. Whole class discussions were often drawn out and left little time for comparison of approaches. Small group conversations, however, allowed students to quickly observe four, often different, approaches and provided specific time for commenting and comparing on each one. As a result, students frequently changed their opinions about the most effective approach during small group conversations after listening to others present. As mentioned earlier, this rarely happened within whole group conversations, where students with existing misconceptions or knowledge gaps frequently were left behind.

Cynthia & Laura. Cynthia and Laura may provide important insight into the role that student engagement plays in terms of the impact of math journaling on student flexibility and reasoning. Cynthia and Laura both began the school year with developing English and math skills. However, Laura became significantly more involved in and confident with the math journaling and peer teaching process than did Cynthia, who only engaged with significant prompting, scaffolded questions, and additional time to respond (this was true of her engagement in literacy lessons as well). As a result, Cynthia saw positive growth only in the areas of modeling (the least language intensive area of journaling) and reflection. Their growth on the NWEA test was also very disparate—while Cynthia showed zero percentile growth, Laura had the highest growth in the class.

Laura's narrative, however, suggests that the journaling and peer teaching process may potentially have a positive impact on students' willingness to take risks and persevere through challenging problems. Both skills are crucial to the Common Core math practice standards and will continue to support students as they gain both math and language proficiency. Initially, Laura wrote nearly nothing each time we used math journals, and would only reply with "No se" or "I don't know what to say" when asked to comment on other students' work. By the end of the research period, her journaling revealed attempts (often several!) at even the hardest problems, and she engaged enthusiastically during conversation. In fact, in an effort to assess her own strategies, Laura asked more clarifying questions of her peers than nearly any other student.

In short, while gains in flexibility were seen across all of the student subgroups, math journaling and conversation had a significant qualitative impact on students with lower language and math skills as well. This may be due to a student's level of comfort with the journaling and peer teaching process. It may be important to provide additional supports for students like Cynthia, such as previewing and practicing contributions to a conversation prior to the whole-group meeting; allowing time to write, rehearse, and read responses; allowing choice in speaking partnerships; and allowing the student to speak in pairs rather than larger groups of students.

Jose & Mayeli. Like Laura, Jose was highly engaged in the math journaling and peer teaching process. He was much more anxious to contribute ideas, share his strategies, and reflect on the strategies of others than Mayeli, who eagerly journaled but needed encouragement to participate in the conversations that followed. As was true for Laura and Cynthia, Jose grew much more in areas related to reasoning (5 points overall across vocabulary use, process writing and reflection) than did Mayeli (who grew 0 points overall in these three areas). Again, for students with developing math skills, it appears that the degree to which students engage in the journal writing and conversation process may have a direct impact on their ability to express their reasoning.

Throughout this research, it became clear that both students had several significant content knowledge and skill gaps, and that math journaling was perhaps not the most effective structure in which to remediate. While they showed typical growth in areas related to math flexibility (modeling and strategy use), their overall strategy use scores were among the lowest in the class and averaged even lower than Cynthia's and Laura's rubric scores. While Laura frequently asked clarifying questions and self-corrected her misconceptions within the journaling process, I frequently had to work with Jose, Mayeli, and Cynthia in a remedial small group *after* the lesson. The structure of a typical math lesson that does not involve math journaling provides ample time for me to support student practice, clarify misconceptions, or modify work for individual students in the moment to better support their needs. However, the math journaling and conversation structures moved at a fast pace and required me to actively monitor the entire classroom, rather than hone in on individual needs. As a result, there were very few opportunities for teacher intervention when student misconceptions occurred. This meant that when students like Jose enthusiastically pursued an ineffective strategy, or revealed gaps in underlying understanding in his journal, I was not able to effectively remediate in the moment. This differed from students with highly developed math skills, who could frequently self-correct their errors while observing the work of others, suggesting that the math journal and peer teaching structure may be useful for providing information about student misunderstandings, but should occur in tandem with additional remediation structures, such as review groups when the lesson is done.

Araceli & Yadiel. Araceli was shy while presenting her work to the class, but she put great care into her journaling and frequently asked for more time to be able to refine her thinking or add more details to her procedure. More than any other student in the class, she was invested in refining her writing to demonstrate her learning and often asked for feedback on her vocabulary use and process writing. Probably as a result she grew more in the areas of reasoning than any student besides Alexia, and had the second highest overall journal rubric score in the four subgroups of students.

Conversely, Yadiel showed the lowest growth in the class, despite having the second highest beginning benchmark score on his overall journal rubric. He was perhaps the only student in each of the four subgroups who was disengaged from the entire journaling process. He always completed the journal, but never used extra time to explore new strategies, challenge himself, or refine his writing. While his strong math skills often led him to use excellent strategies, he resisted presenting to the class. When he did so, he was not very descriptive and did not engage well with questions or feedback from his peers. Again, the discrepancy in growth between Araceli and Yadiel, particularly in the areas related to reasoning, further suggest that the degree to which a student is engaged in the journaling and peer teaching process has a strong positive impact on their growth, particularly in the area of reasoning.

Interestingly, when reflecting on Yadiel's engagement in this process, I realize that he spent a great deal of time helping out a student with some significant learning needs who sits next to him (and is not a part of any subgroup in this research). While Yadiel's work did not improve as much as I would have liked, the work of Roel, his neighbor, improved dramatically. I don't doubt that some of Roel's success can be attributed to Yadiel's qualitative growth in math and the leadership he gained through this process. The journaling and conversation process are highly focused on the thinking of *individual* students, but Yadiel and Roel's experience may suggest that some students might benefit more from the structure if journaling were done collaboratively.

Alexia & David. Even towards the end of the school year, David 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, to some extent, 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's work suggests the presence of "soft skills" that these rubrics and measurement tools do not capture, such as stamina and self-motivation. I have never seen a student persevere through math challenges the way Alexia does; her journals were filled with multiple attempts at the same problem, efforts to solve the problem in new and innovative ways (even if there were easier routes to an answer), and consistent tries at integrating recently-learned strategies. These are skills that I did 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).

Conclusions and Recommendations

Throughout the action research process, I indeed saw how math can serve as what Moses and Cobb (2001) describe as a "gatekeeper and a sieve" for student success. The math journaling and conversation process revealed that students' facility with the academic language of math is often deeply connected to their abilities to present their reasoning clearly. I also saw that students with stronger math skills were more likely to engage in discussion, take risks in communicating their ideas, and reflect on their own work. While the math journaling and conversation process certainly did increase math flexibility in my classroom on the whole, it became clear that these structures benefited certain students more than others.

These conclusions lead me back to the research of Moses and Cobb (2001), who state that "Today...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" (p. 5). Students who became empowered to be flexible in their math choices and defend those choices with increasingly powerful language may later translate these skills to what Delpit (1995) described as a larger "culture of power" in our society, which continues to be accessed primarily by those who are white, middle-class, and English speaking.

However, becoming empowered with the language of math may open gates for my language learning Latino students to better access that culture of power. Through the math journaling process, I saw evidence that even students with developing English skills (like Laura) strengthened their confidence in presenting and defending their ideas in front of others. To do this, students had to carefully plan how they would present and model information to their audience (the larger classroom or subgroup) and provide compelling arguments for the strategies they chose. I believe these skills, taken out of the context of math, will lead my students to be better self-advocates for their ideas (academic and otherwise) within the larger culture of power that exists in college, the workplace, and society as a whole. Furthermore, the math conversation process required students to listen to, synthesize, critique, and compare the ideas of others. This process often led them to revise or recommit to their own strategy choices. My students will use this experience of considering the diverse opinions of others in their future academic careers and beyond. I hope that the math conversation structure has helped them begin to do so in a way that shows both critical and flexible thinking.

Based on this action research, I draw conclusions and make recommendations below.

Teacher Level

Students benefit when teachers both teach and practice skills with them at least once a week for 20 minutes beginning at the start of the school year. Teachers should strategically teach and help students *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. This will require teachers to carefully identify the skills and knowledge embedded in strong math conversation (such as adding to each other's comments, being specific with vocabulary, and asking clarifying questions) and to plan for, model, and practice these skills. Likewise, teachers should identify the skills needed to reason through math in writing (such as using sequence language, referring to models with precision, and using logical connectors) and include writing as an integrated part of math instruction.

This research also reveals that math journaling and conversation can be used as tools to engage students with developing math and language skills, and to fortify their abilities to model their thinking. As in the instance of Laura and other students with developing English skills, the math journaling and conversation process supported more efficient math strategy use and increased flexibility regardless of students' English language development. Likewise, math conversations had a strong qualitative impact on students' engagement, confidence levels, and oral reasoning, even when they struggled to communicate the same thoughts in the written journals. Math journaling and conversation should not be used as a means for remediation, however. Rather, teachers should continue meaningful math remediation and intervention, and use the math journaling and conversation time to help struggling students present learning that has been solidified.

School Level

To engage in meaningful math conversation, students need to build skill with the “math register” mentioned earlier. To this end, schools should seek to define this math register collectively, and to commit to standardizing language, conversation norms, and math structures so that students’ conversation skills build from year to year. 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.

Curriculum level

Colleagues who have read this research or observed my math instruction have described two potential barriers to implementing the math journaling and conversation structure themselves. First, it can be time consuming to craft meaningful, open-ended, multiple path problems for math journals every day. However, the Common Core State Standards and the PARCC assessment that accompanies them demand this type of problem solving and student discourse. Math curriculums should provide two to three examples of potential discussion or journaling questions to accompany most unit objectives, so that teachers are able to select one that suits the need of their individual classroom.

Second, it can be challenging to anticipate all the possible student responses and misconceptions around which a math conversation can be structured. Many teachers, particularly elementary teachers who must plan for multiple content areas, are still getting accustomed to the content knowledge embedded in the Common Core State Standards. This means that some educators struggle to identify the prerequisite knowledge and skills a student needs to meet a math lesson objective and therefore are not able to anticipate where students may struggle within a lesson. Curriculums can support teachers by identifying common student misconceptions and errors and providing teachers with potential responses or interventions for supporting students when they occur.

Author Notes
Lindsey Schmitz is a teacher at Chavez Elementary School in Chicago.

Correspondence concerning this article should be directed to Lindsey Schmitz at lgdickerson@gmail.com.

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Appendix A: 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**			

Appendix B: 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**			