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Teaching Problem Solving In Mathematics: Cognitively Guided Instruction In Kindergarten

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TEACHING PROBLEM SOLVING IN MATHEMATICS: COGNITIVELY GUIDED INSTRUCTION IN KINDERGARTEN

By

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To my Mom who motivated me to do the impossible and to my family and friends who made it possible. Thank you to my Capstone committee for guiding my journey, to the volunteers who made the video conferences possible, to my kindergarten colleagues who joined the adventure and to my husband and extended family who supported me throughout this process. Last but not least, thank you to the kindergarten subjects for keeping your minds focused and your hearts caring.

"We always hope for the easy fix: the one simple change that will erase a problem in a stroke. But few things in life work this way. Instead, success requires making a hundred small steps go right - one after the other, no slipups, no goofs, everyone pitching in."
― Atul Gawande,

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CHAPTER 1

I never liked math. In fact I hated it. My hatred for math simmered throughout my elementary and middle school years and culminated into a moment where a teacher I adored recommended that I no longer pursue math classes. This was presented in high school as an attempt to preserve my GPA, but I always wondered if he too, thought I was hopeless in math. I was in Gifted and Talented in elementary school so adults assumed that I was not trying- but the truth was I did not understand math. Somewhere along the way I had lost the ability to solve mathematical problems. I memorized rules and would study really hard- but it just wouldn't stick. I found myself repeatedly looking up vocabulary words and simple formulas just to finish a single homework assignment. Cumulative tests were impossible. My mother, a former math teacher, tried to help but also wound up frustrated. I gave up.

My experiences teaching have shown me that my own roadblocks in math are not unique. Years later when I taught Title I math classes for students that were below grade level I saw the same pattern over and over again. Students would half-heartedly memorize a procedure, try to apply the procedure and only get the correct answer to a problem if they were lucky and meticulous. If they got off track they would not be able to recognize that they were making a mistake, and they would be baffled that they got an incorrect answer or they would see that they had made a mistake but be unable to find their error and give up. In addition, the students that I taught in Title I did not know the language of math. Some of them were fluent in math facts, but still unable to function in application of mathematical concepts. They struggled with recalling what they had previously learned. I found ways to teach them that helped them with the struggle of the moment, but I felt ineffective at tackling the larger problem, higher level thinking.

As a teacher, I had been trained in Cognitively Guided Instruction practices (CGI), but I also was presented with a curriculum that was designed for explicit instruction. First the teacher models how to solve the problem, then the teacher and the students work on many problems together that are similar in nature, and last the student attempts to tackle the same type of problem independently.

I quickly discovered that this approach did not work for the majority of the students that I taught. They were disengaged. When I provided them with the strategy or the procedure and then we repeatedly practiced the same strategy over and over again they were not required to think. This approach did not value their thoughts and ideas, it did not connect them to other mathematical ideas, and it required no sense of place value or critical thinking. Teaching strategies to struggling math students was a temporary fix at best. If we missed a day or two, all learning would be lost and we would start back at the beginning.

I got permission to use CGI with one of my math groups and decided to tackle multiplication facts by discussing the strategies that we used. In the beginning, my 4th graders only talked about short-cuts and poems that they had memorized. I got out manipulatives and started asking them to model for me. We spent a long time modeling multiplication facts and discussing famous mathematicians who find patterns and make strategies. One day a boy in the group, let’s call him Troy, shared a strategy he was using to multiply by 7’s. It was an approach that I could hardly follow and it only worked with odd numbers, but it was his! We named it after him and I made a point to refer to his strategy a couple of times each week. Troy changed. His thinking was valued and he began to speak up in class. He looked for patterns in math and he got his 7's that were multiplied by odd numbers consistently correct. By the time he left my group, he had started to develop a bit of confidence and was establishing other strategies and making some connections to other mathematical ideas. He changed me, too. I began to see that teaching is more about getting students to think for themselves and less about getting the correct answer every time.

My personal transformation with math was a slow process. I had to relearn almost everything that had been taught to me as a child. I started with remedial math classes at my local community college. I was the student that our high school teachers had warned about, the one that had to pay for knowledge that had once been offered for free. I was enrolled with many students who were learning to speak English for the first time, fresh immigrants from other countries that understood the math and were really learning language. It was humbling. I stuck with it because I had realized how important math skills are to succeed as an adult. Almost any career of interest required a certain level of math. As a young adult, I had found myself stuck without math. If I wanted to pursue a career, or balance my budget, or move out of my parent's house, something was going to have to change. I was determined to be successful because my future depended on it. I was not only motivated to learn, but I was also invested.

As an adult, I found math less difficult. I believe my brain was finally ready to handle the concepts being taught. I was able to discern what the overarching mathematical concepts were in comparison to the shortcuts being taught for computation.

I started at the very beginning, filling in all the missing holes. This time I paid attention to the language of math. I would make flash cards that not only defined new vocabulary or concepts, but also contained an example. I used the language of math in class. I studied hard, but this time it paid off. I retained what I learned and soared through my math classes.

Cognitively Guided Instruction

As I prepared to become an educator, I took a class in teaching mathematics in the elementary school. This class was taught using Cognitively Guided Instruction practices (CGI). Our professor asked me to do things I had never had to do before. For example, he presented us with math problems that we were supposed to compute mentally, no paper or pencils allowed. He also stressed that we think about and discuss our mathematical thinking. We would spend a fair amount of our time talking about how we reached our answers. Learning about math using CGI was when I became aware of multiple strategies for the first time. I began to see how the brain can give us clues as to what is developmentally appropriate for each student. CGI also fit well with the social learning theories that were at the basis of my educational philosophy. Learning CGI cemented the mathematical concepts I had been studying and opened up the arena of math for exploration. Teaching math suddenly was open to creativity and discovery. I was sold.

Today math is my thing. One of the things that I love the most about mathematics is it is something that I used to misunderstand in the past. I used to believe that math was all rules, that there was no room for inspiration or interpretation. Now I understand math differently. I know that like all higher-level knowledge math can be unique and clever. I have learned that math is not easy or simple because it is not strictly sequential. A student can be high in one area of math and low in another. This makes math a little bit like the Wild West. In some ways how math is understood by each individual is uncharted and undiscovered. It is messy and complicated too. I find myself wondering what may have happened for Troy and myself if we had been able to develop a strong foundation in math at a younger age. Would our educational experiences have been different? Our self-esteem? Our careers?

Going Forward

I want to help my Kindergarten students build a strong foundation in math so that they are set up for success in later years. I hope to intervene before they struggle and give up in math as I did. My experience has taught me that these students will need to explore math in order to be able to remember what they are learning and to recognize the big concepts. I also have learned that mathematical language will need to be cultivated and developed. But I want to take my teaching even further, and promote higher level thinking skills. I believe that if I can get students to slow down, reflect and use another area of their brain to record their mathematical ideas I may be able to facilitate higher-level thinking. The question I wish to address with this capstone is;

How does using a combination of whole class and small group conversations, along with individual math conferences, impact the rate of growth in problem solving and language development in kindergarten students? In the next chapter I will review literature related to teaching strategies that are utilized for problem solving in mathematics. I will explore the existing research on these topics and make the connection between this study and the current research. In Chapter Three I will discuss the Quantitative Method research approach with an experimental method plan that I will use in my study. I will use a pre-experimental design using an alternative treatment Pretest-Posttest with a Nonequivalent Group format (Creswell 2014). In Chapter Four, I will share the results of my research. Finally, in Chapter Five I will conclude my capstone with implications for how this study can be applied to classroom teaching. I will research and compare teaching strategies for increasing problem solving skills for students using my students and their achievement as a means for validating or refuting what I find.

CHAPTER 2

Introduction

One of the big questions that every teacher struggles with is how to reach each and every student. This conundrum is one that has been grappled with since the beginning of teaching and in America it has been the basis of sweeping legislation such as No Child Left Behind and the Every Student Succeeds Act, as well as programs to meet the needs of specific groups of students like Gifted and Talented, Response To Intervention, and Title I. No single law or program has yet solved the problem of how to get each and every student to grow in their learning. This is particularly true when it relates to higher level thinking skills like problem solving. Students, like myself and the ones that I worked with in Title I, can be found in every classroom. These are students who lack mathematical reasoning and number sense are left unable to solve simple problems at the end of their educational experience (Burns, 2007).

Problem solving is a basic skill students will need to solve many types of challenges that they face as they grow into contributing members of society. Problem solving is important because with this skill students will be able to persevere and reason through all types of situations that arise. Kindergarten is a valuable time to create a solid foundation for problem solving because this is a time where students either learn how to connect what they already know to school or learn that school and home are separate and disconnect academic learning from their background knowledge. It is often a time when students are first introduced to formal math instruction, and that first impression is important.

Language is a prerequisite to problem solving development because according to Toll and VanLuit (2014), “language is one of the main inputs for learning, and for this reason, the acquisition of early numeracy skills is highly dependent on basic oral language” (p. 65). Students cannot tackle problem solving skills until they have a foundation in language.

This leads me to ask: *How does using a combination of whole class and small group conversations, along with individual math conferences, impact the rate of growth in problem solving and language development in kindergarten students?*

In this chapter the questions above will be addressed by reviewing the recommendations that are found in current research. Problem solving in mathematics and the skills that are required to be successful in this area will be reviewed. Elements of problem solving that prevent students from finding the correct solutions will be covered, along with some of the best practices recommended for teaching problem solving to elementary and kindergarten students.

Language and vocabulary in relation to mathematics instruction will be reviewed. Obstacles that stop some students from developing mathematical vocabulary will be addressed and recommendations for teaching mathematical language skills and vocabulary will be shared. Finally, the connections between language and problem solving will be drawn.

Cognitively Guided Instruction (CGI) including what the characteristics of it are and why it is important will be explored next. Three major characteristics of CGI; that it adjusts to cognitive development, that it teaches and uses metacognition, and that it also often utilizes cooperative instruction will be covered. Counter arguments to CGI will be addressed. Finally, the teacher's role in CGI-based classrooms and how it connects to problem solving in kindergarten will be reviewed.

The chapter will close with the connections between research revealed here to the study performed, along with the study's benefits and challenges. This study will be related to the larger field of education and the main findings discussed in this chapter will be summarized.

Problem Solving

Mathematics instruction for teaching problem solving skills seems to fall into two basic categories; exploration and direct instruction. There is a growing body of evidence that suggests teachers should allow students to investigate mathematical principals before receiving teacher directed instruction in the development of problem solving skills. Indeed, some perspectives believe that mathematical exploration should replace direct instruction entirely, that providing models and algorithms hinders student learning in mathematics.

The literature reveals that problem solving is most commonly taught through three types of instructional strategies: 1. Teach cue words that give operation hints; 2. Teach algorithms (also called solution strategies)(Fuson & Willis, 1988); and 3. Encourage students to invent their own solution strategies. Cognitively Guided Instruction (CGI), the approach used in this study, falls under the third category.

Teaching problem solving is important because it allows students to become more independent. In addition, critical thinking is valuable because the Common Core Math

Standards for Mathematical Practice (NGA Center and CCSSO, 2013) are all connected to problem solving in math (Strom, 2013). In the current atmosphere of accountability and high stakes testing anything connected to the Common Core has to be valued if a teacher is going to ensure success for their students. Problem solving is important in kindergarten because it allows students to reach high levels of achievement at the beginning of their educational career. “The intuitive strategies kindergarteners bring to mathematics, along with a classroom in which the teacher engages children daily in problem solving, allow these young children to solve problems that are much more complex than we have traditionally thought possible” (Wedekind, 2011, p. 102). Problem solving, like many other skills, is developed with practice, starting in kindergarten allows students to practice immediately and it also allows students to maintain and grow in their intuitive strategies.

Another reason why teaching problem solving in kindergarten is critical is that it builds upon the mathematical strengths that students already have instead of alienating those strengths, “if older children would simply apply some of the intuitive analytic modeling skills exhibited by young children to analyze problem situations, they would avoid some of their most glaring problem-solving errors” (Carpenter, Ansell, Franke, Fennema, and Weisbeck, 1993, p. 429). If we acknowledge and affirm the mathematical strengths that students bring with them as incoming kindergarteners, then we may prevent later mathematical struggles that are a result of ignoring early mathematical reasoning.

Another reason that problem solving is important is that students who do not do well in problem solving are at increased risk of experiencing math anxiety, which is related to low math confidence and can hinder a student’s ability to learn math (Dutko, 2015). The subjects of this study are kindergarteners who will be setting a trend for their future education. It is imperative that as educators we do all that we can to protect them from adverse outcomes of education such as math anxiety.

Skills Needed for Problem Solving

A large variety of skills have been identified as necessary components to problem solving. One of the most important problem solving skills is the ability to construct a model or representation of a problem (Carpenter et. al., 1993). A student must be able to hear or read a problem, understand the problem, and accurately construct a portrayal of the problem. When studying prekindergarten and kindergarten students Charlesworth and Leali discovered that in addition to content knowledge, there were four processes that students need to be able to apply to successfully problem solve; reasoning, communication, connections, and representation (2012). Reasoning, communication, connections and representation are all higher level thinking skills that each have their own batch of techniques that are necessary for success. In addition, executive functioning and working memory are necessary for effective problem solving (Irwin, 2013). Students must be able to hold ideas in their memory and think at a deeper level to problem solve.

Blocks That Prevent Problem Solving

Motivation refers to a student's desire to accomplish a problem solving task. It is one of the biggest obstacles that teachers face because motivation can be affected by anxiety, self-efficacy, and countless other factors (Dutko 2015). Students can lack the motivation to even begin solving a mathematical problem, or they can be unmotivated to try things in a new way (Gourgey, 1998). When students are unmotivated it excludes them from the learning process that is occurring in the classroom.

Students also can be remiss in using reason or context to solve a problem. In 1983 students were given a problem on the National Assessment of Educational Progress that required them to calculate how many busses would be needed to fit a given amount of soldiers. The problem did not divide evenly and only 1/3 of students tested recognized that they needed to round up the number of busses to correctly answer the problem (Carpenter et. al., 1993). Although students were able to calculate an answer correctly, they did not use reason to determine the need to round up.

Best Practices for Problem Solving

One way teachers can impact problem solving development in kindergarten students is to provide them with opportunities to count. Wedekind (2011) asserts, "While counting may seem like a simple skill for adults, counting for Kindergarteners involves a great deal of problem solving" (p. 105). Teachers should provide students with an abundance of opportunities to count objects and facilitate conversations about how objects have been counted.

Another way that teachers can impact problem solving is to scaffold students existing mathematical knowledge. Carpenter et. al., (1993) recommend that teachers "help children build upon and extend the intuitive modeling skills that they apply to basic problems as young children" (p. 429). Utilizing the preexisting knowledge about mathematics that kindergarteners bring to school allows students to, "construct strategies that make sense to them rather than parrot strategies that they do not understand" (Jacobs and Ambrose, 2008, p. 260). Mathematical conversations provide a venue for students to explore strategies and connect their preexisting knowledge to classroom mathematics.

Teachers also should respond to what their students are doing. Jacobs and Ambrose (2008) assert, “In the midst of instruction, the most effective moves arise in response to what a child says or does and, therefore, cannot be preplanned” (p. 261). Teachers should be flexible and adapt to their learners in the moment of instruction. This requires the teacher to have solid background knowledge about how students develop and grow in mathematics so that they can facilitate mathematical conversations in a manner that encourages student growth.

Vocabulary & Language

Research has revealed a strong connection between language development and math. Toll and VanLuit (2014) studied this connection and found that communication and math are so closely connected that a kindergarteners’ print knowledge is known to be a substantial predictor of a child’s early numeracy. They also discovered that one of the skill sets for successful communication is knowledge of language, a knowledge of vocabulary and a knowledge of grammar (Toll & VanLuit, 2014). Finally Toll and VanLuit concluded, “children lagging in language development are at a disadvantage when it comes to early numeracy development.” (2014, p. 65). Vocabulary and language are foundational skills that impact mathematics and as such are integral components of mathematics instruction.

Blocks to Developing Language

There are many aspects of language development that can be difficult for students to overcome. Research shows that one of the troubles students face is the unique vocabulary of mathematics which can serve as an obstacle for students who otherwise perform well with language (Toll & VanLuit, 2014). In addition, math vocabulary is tricky because many of the words have multiple meanings that are different in everyday context and many words related to math are specific only to the discipline (2007, Burns). It gets even more complex because students need to understand more than just vocabulary. They also need to know how to apply prepositions, sentences and phrases to be able to accurately understand the word problems that are presented to them (Jjitendra, Rodriguez, Kanive, Huang, Church, Corroy & Zaslofsky, 2013).

Students have to have an understanding of the concepts that mathematical language identifies, if they don't understand the underlying concept then they won't understand the meaning of the mathematical word (Burns, 2006). This means that teachers need to be able to introduce students to mathematical concepts without relying on mathematical vocabulary. Language development as it relates to mathematics is complex, and as such requires careful instruction.

Best Practices in Teaching Language

The complex nature of language development means that it is imperative that teachers model the use of mathematical language in a manner that is intentional and mindful. "Simply becoming more aware of and more deliberate about our teacher language (what we say, when we say it, how we say it) is one of the most powerful and reflective decisions we can make as teachers" (Wedekind, 2011, p. 72). It also is important to model academic mathematical language in context because, as Toll and VanLuit (2014) discovered it has a positive impact on kindergarten students' mathematical language development.

Mathematical conversations will create a space for students to use language, but it is still important to provide some scaffolding. Wedekind (2011) found that it is important to provide tools and manipulatives for students so that as they share they are able to model aspects of math that they are not able to verbalize yet. Mathematical conversations provide room for students to practice academic vocabulary as they try to communicate their important ideas. Teachers can then seize upon the moment and insert language and vocabulary directly into mathematical interactions where students are invested in developing language to communicate.

Other ideas for promoting mathematical vocabulary development include, "cooperative learning, using journal writing, and having students develop personal glossaries" (Bruun, Dias and Dykes, 2015, p. 532). While journal writing and personal glossaries might be challenging at the kindergarten level, cooperative learning is easy to accomplish with mathematical conversations.

Connection to Problem Solving

Language development and problem solving are both skills that need to be addressed in mathematics instruction and mathematical conversations allow for both to be taught simultaneously. Toll and VanLuit (2014) conducted a study to examine the connection between language and mathematics in low achieving students. They found that, “Both skills—early numeracy and basic language—appear to be related to each other in typically developing children, and these skills, like other cognitive skills, are likely to mutually influence each other during development”(p. 65). Development in one area affects development in the other area, so that growth in problem solving ability would also impact a students’ language development. Toll and VanLuit (2014) went on to assert that, “understanding how children’s higher-order language skills interfere with or support the development of numeracy proficiency appears to be critical to closing the mathematical achievement gap at a later stage in the educational career of those children.” (p. 65). At the end of their study, Toll and VanLuit argued that, “The present data confirm the hypothesis that specific math language is an intervening variable within the developmental relation between general oral language and early numeracy, therefore stating the importance of specific math language in early numeracy” (p. 73). One of the best things that teachers can do to increase mathematical ability in students is to instruct them in the language of mathematics at an early age. This could be done through the facilitation of student discussions pertaining to math.

Cognitively Guided Instruction

Cognitively Guided Instruction (CGI) is an approach to teaching mathematics that emphasizes exploration and utilizes mathematical conversations. The foundational thesis behind CGI is that students already have knowledge about mathematics when they enter school that can and should serve as the basis for comprehending formal primary curriculum and standards (Carpenter, Fennema, Franke, Levi & Empson, 1999). This belief is in line with constructivist theory that also views mathematical reasoning as a type of logico-mathematical knowledge that is created from mental relationships and can be done individually vs. social knowledge, which is passed from person to person (Kamii and Dominick, 1998). This perspective would explain how students are able to come to school with preexisting knowledge about math as well as the need for student interaction in mathematics.

CGI is not a curriculum or a formatted sequence that teachers use to create their lessons. Johnson researched CGI in 2013 and stated that “CGI is not a teaching method, that teachers are not told how to teach, but armed with information that should guide their teaching.”(p. 29). Carpenter et. al. describe CGI as “understanding how children’s mathematical thinking develops and reflecting on how to help children build up their concepts from within” (1999, p. xiv). Carpenter et. al. (1999) also state that CGI seeks to create a classroom environment where children are encouraged to develop strategies and utilize procedures that are meaningful to them instead of determined by the teacher. Teachers are equipped with vast background knowledge of mathematical cognitive development in CGI and are able to show flexibility in instruction and respond to students in the moment of learning. Metacognition is utilized in CGI as students discuss how they found an answer to a problem or developed a strategy and cooperative learning is used as students work together in solving mathematic problems and creating new understandings.

Why CGI is Important in Kindergarten

CGI is an approach that accounts for cognitive development. Research shows that kindergarteners come to us with an ability to solve many types of problems, including multiplication and division (Johnson, 2013). Kindergarteners also are able to strategize how they solve a problem Wedekind (2011) asserts "Many kindergarteners stay within a realm of direct modeling strategies…and yet not all modeling strategies are created equal"(p. 117). This provides an opportunity for in-depth learning. Teachers should build understanding off of what students already know about math. How a student performs in kindergarten math will not only predict their later math achievement, but also reading achievement, their rate of progress in learning, and their chances of having a STEM related career (Irwin, 2013). This means that we need to get kindergarteners operating in high-level math such as problem solving quickly and efficiently so that we can set them up for later success.

Another reason why CGI is valuable in kindergarten is that CGI focuses on constructive abstraction, which advances numerical reasoning (Kamii, Kirkland and Lewis, 2001). This means that CGI allows students to not only make sense of math but also is encouraging student mathematical cognitive growth. Research shows that those that do not do well in kindergarten math are at high risk for facing later mathematical difficulties (Toll & VanLuit, 2014). Kindergarten is when students set the trend for later mathematical achievement which makes mathematical instruction at this age extremely important.

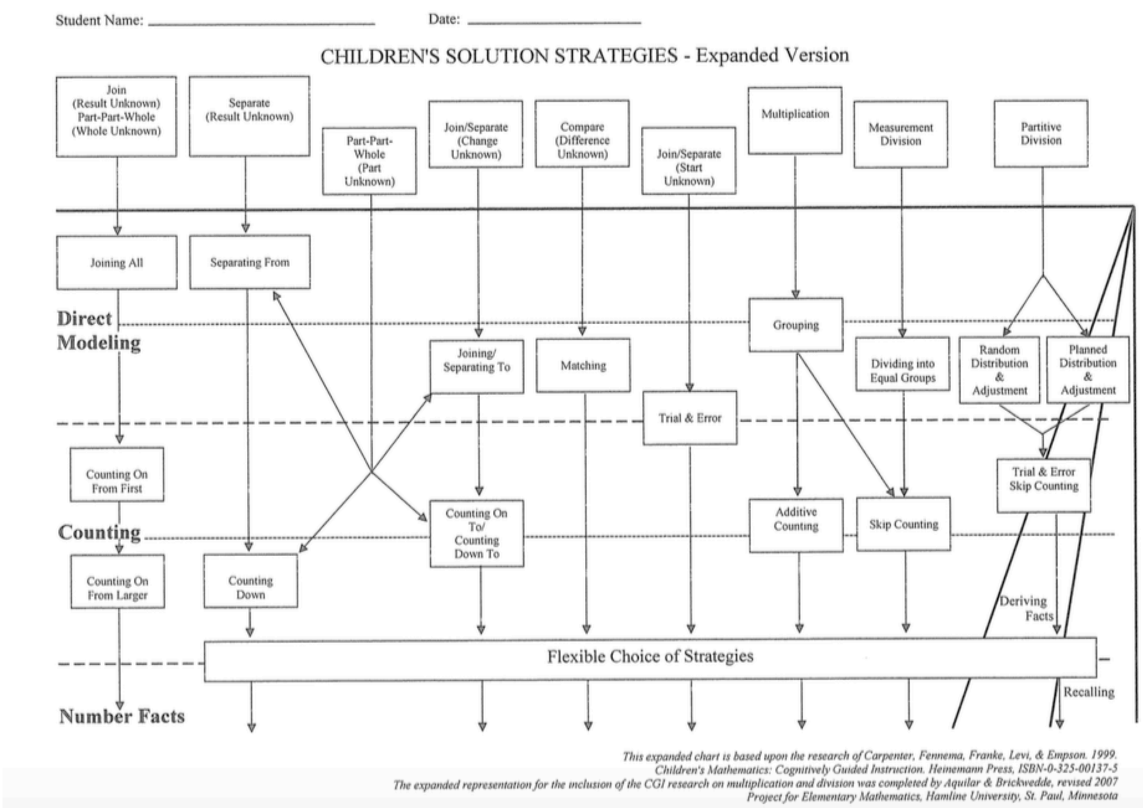
Cognitive Development

The researchers who created CGI have been credited with having uncovered the connection between cognitive development and mathematics problem solving (Johnson, 2013). Posing word problems and developing problem solving skills is a cornerstone of

CGI. Through the lens of CGI, word problems can be categorized into many specific groups. Carpenter et al. (1999) identified four categories for addition and subtraction problems known as Join, Separate, Part-Part-Whole, and Compare. Join and Separate are types of problems that involve action, similar to watching a movie. Something changes over the span of time. In contrast, Part-Part-Whole and Compare problems look at mathematical relationships, similar to a photo that has been taken. Each category can be further specified by identifying the portion of the word problem that needs to be solved (Carpenter, et al.,1999). Carpenter et al. (1999) also categorized multiplication problems. At the kindergarten level multiplication with grouping is the category that will be relevant.

Carpenter et al. (1999) mapped the developmental sequence that most students follow when they solve various problem types. This sequence is that first students will directly model a problem to solve it, then as they develop they begin using counting methods. The last strategy to develop is using number facts to solve a problem. Carpenter et. al developed a visual map of solution strategies and Aquilar & Brickwedde (2007) further adapted the solution strategy map to include additional problem types (Figure 1).

Figure 1 Children's Solution Strategies



Complexity of Development

Cognitively Guided Instruction is one approach to teaching math that accounts for the complexity of mathematical development and the wide range of development that occurs in math. This is important because at the kindergarten level there is a large scope of numerical knowledge amongst students as well as vast differences in cardinal and ordinal competency (Wright, 1994). The complexity of mathematics instruction is difficult because there is not one specific route of development in mathematics. Johnson (2013) goes on to describe this process as, "a complex individual process that combines factors related to the student, the problem and the problem context." (p. xiii). This means that differentiation and an exposure to other ideas and levels of thinking are critical components of mathematics instruction. These types of discussion also reveal student thinking which allows a teacher a lens into a student's level of abstraction. This is valuable because students are only able to give meaning to symbols or manipulatives that are at or below their level of abstraction (Johnson 2013). Teachers then must present new concepts in a level of abstraction that is attainable for each student. Teachers must have a strong level of mathematical knowledge to be able to teach abstract notation in a manner that is understandable to students (Hu, Fuentes, Wang, Ye, 2014).

Kindergarteners are developing their ability to conserve and abstract which can greatly affect how they learn math. Until students are able to master a specific level of constructive abstraction they do not use logic to understand the world around them. Before they are able to conserve, the tools we use in the classroom, such as manipulatives or drawings, will not represent an object in reality to them. They are unable to understand the concepts represented (Johnson, 2013). In essence, if a student has not conserved the number 12 and we present them with a mathematical problem using that number, they will not be able to understand 12 or what we are doing with 12. They may be able to mimic our behavior, but it will be without meaning, much like students who memorize procedures but lack the connection to number sense.

To make matters more difficult, students are not all at any one particular point in development at any given time. In fact, they can perform at a variety of levels across the different types of word problems; which indicates that they are able to move through multiple stages within a given range. (Johnson, 2013). An example of this would be a student that is still in early stages of counting down in subtraction, but is able to divide using equal groups.

CGI is able to meet the varied needs of students through the types of discussions that occur as students explain their mathematical thinking. During this process, students are exposed to ideas at levels both above and below their own level of understanding and there are a variety of viewpoints for students to be able to relate and connect to. Wedekind (2011) states that, “the focus should always be on what the child already knows and almost knows and how to teach them from that point on” (p. 102). CGI allows differentiation to occur during whole group and small group instruction through the exposure to peer discussions about math.

Cooperative Learning

CGI lends itself well to cooperative learning because students are dependant on exposure to one another’s thinking. Cooperative learning is in it’s nature inquiry-based, child centered, and differentiated (Hu et. al., 2014). Both cooperative learning and CGI are methods that use exploration through posing problems for small groups of students to solve collectively and in doing so, students become invested in their own learning and that of the other people in their group (Tarim, 2009). Allowing students to investigate mathematics with peers creates room for the development of social skills Wedekind (2011) explains that, “The talking, negotiation, compromise, and problem solving kids run into when counting a collection of objects with a partner establish a strong foundation of interdependence and cooperation in the classroom” (p. 105).

In 2009, Tarim found that by facilitating cooperative learning in the classroom preschool aged students were able to statistically increase their mathematical problem solving abilities as well as the social skills of cooperating, sharing, completing group work, listening, and following directions. If preschoolers are able to be successful in this type of learning environment then it stands to reason that it should be attainable for kindergarteners as well.

Types of Discussion Used

Both CGI and cooperative learning practices are grounded in using discussion as a format for learning. It is important to note that there are a couple of different discussion types that can be used for various purposes. Discussions can be focused on strategy sharing, where students share a wide array of strategies for solving a given problem, or discussions can be focused on evaluating a specific mathematical idea with a more focused sharing of strategy (Hintz & Kazemi, 2014). Hintz and Kazemi explored the different types of mathematical discussions that benefit student learning. They found that "The way teachers and students talk with one another is crucial to what students learn about mathematics and about themselves as doers of mathematics" (p. 40). The types of discussions that teacher's initiate in their classrooms plays a very important role in a student's understanding of mathematical concepts and in student efficacy particularly in a student-centered approach such as CGI. It is valuable that conversations are student led and centered because this allows students to broaden their learning (Burns, 2007).

Metacognition

Metacognition is a skill that students need to be able to participate in mathematical conversations. Metacognition is the awareness of ones thinking processes. This approach to learning has been defined as the recognition of what one does and does not understand. It allows students to reflect and oversee their own progress, and to connect to new understandings (Gourgey 1998). In metacognition, students are exploring their own minds. Metacognition is an inherent element of CGI because students have to recognize and remember what their thinking processes are in order to be able to communicate them to their classmates.

Metacognition is what allows students to become aware of and change their own thinking processes. This skill is an important and fundamental strategy that all students need because it will give students ownership over their decisions, both mathematically and in their home life because they will be able to weigh options and evaluate the decisions that they make as well as learn from previous experiences. Metacognition links home and school by creating deeper learning and by providing a venue for connections to be made across contents and settings, which leads to better retention of knowledge (Gourgey 1998). In addition, metacognition exercises executive functioning, an ability set that is malleable, a mediator of number sense and a predictor of achievement in mathematics (Irwin, 2013).

Metacognition is characterized by discussions of thinking processes. In mathematics class, students would review and discuss the thinking process that led them to a conclusion about a word problem, just as they do in CGI. They also would evaluate their cognitive process and solution as they worked to make sure they are on track to solve the problem, which is also the same as CGI practices. In this environment teachers can use classroom discussions as a way to assess students formatively (Hu et. al., 2014). At the same time students can be aware of and evaluate their own cognitive processes. The difference between CGI and metacognition is that metacognition can be used across disciplines while CGI is used in math.

Counter Research Arguments to the CGI Approach

Proponents of CGI include Fyfe, DeCaro and Rittle-Johnson (2014) who conducted a study that supports modeling instruction when it relates to mathematical concepts and found that there is a high likelihood for misconceptions when mathematical concepts are not directly instructed. Modeled instruction for problem solving in mathematics often involves a teacher showing students how to solve a word problem. Teachers will explain their thinking processes and at times provide students with a framework for solving problems. The problem with using this approach is that it teaches a student to focus on individual steps instead of logical reasoning (Kamii and Dominick, 1998). Kamii and Dominik (1998) have claimed that modeled instruction is harmful to students because students lose their knowledge of math concepts when they are focused on rules and algorithms and this can cause a regression in place value and a prevention of number sense. In addition, it sends a message to students that they are unable to understand math in a greater sense and leaves students stranded with no back-up when they get off track using an algorithm. Students need to understand how mathematical concepts interact in order to be successful (Burns, 2007).

One problem with the Fyfe et. al. (2014) study was that it excluded all of the students who scored above 75% on pre-test measures. The exclusion of this data leaves a gap in research about students who achieved over 75% on the pretest. Would they have benefitted from teacher-modeled instruction or would that group of students be better served by an exploratory approach like CGI? Another major flaw in this study was that the outcome was concerned with correct answers and correct procedures vs. increased concept development, “prior instruction facilitated the generation of correct procedures.” (Fyfe et. al., 2014 p. 511). The CGI lens would challenge this finding, because a correct procedure is subjective to social expectations.

Other questions about CGI requiring further exploration include the fact that the kindergarten age group has not been thoroughly researched at this time. The few studies that have been done have included small sample sizes. The most significant of these studies, Carpenter et. al. (1993), consisted of 70 participants from two different schools and, “Both schools served diverse populations”(p. 431). More kindergarten classrooms from a variety of schools should be studied to see if the new classrooms have similar responses to CGI that have been discovered in previous studies. In addition, there exists a need to further study a prekindergarten level of development to be able to fully encompass Kindergarten.

Teacher’s Role in CGI

In the CGI lens, the teacher is the facilitator of mathematical learning through exploration and discussion with peers. “A classroom rooted in CGI philosophy uses problem solving as the main vehicle of mathematics instruction and understanding”

(Wedekind, 2011, p.29). Teachers pose mathematical problems and observe how students solve them; they use the information gained to make conclusions that allow them to differentiate instruction to an appropriate developmental level. This sounds much easier than it is in actual practice as it can be difficult to expose students to new concepts without misleading them (Hu et. al., 2014).

Additionally, the teacher is also responsible for conveying the aspects of mathematics instruction that are social constructs; such as vocabulary and mathematical symbols. Teachers should be careful to teach vocabulary after they have exposed students to new concepts and ideas so that they can connect their new words in a way that is meaningful and then continue to use vocabulary consistently in a variety of ways. (Burns, 2006). New vocabulary should be written down and teachers should encourage students to consistently use mathematical vocabulary in discussions and assignments as well as model use of mathematical vocabulary themselves (Burns, 2006).

Summary of CGI

One of the major components of CGI is the exploration of mathematical principles. From this strategy students gain meaning through discussions characterized by metacognition and cooperative learning that teachers scaffold for the discovery of new concepts. Carpenter et al. (1999) believe that, “With opportunity and encouragement, children construct for themselves strategies that model the action or relationships in a problem. Similarly, they do not have to be shown how to count on or be explicitly taught specific derived facts” (p. 3).

CGI emphasizes student’s making sense of not only the question being asked, but also the approach they are taking to solve the problem. This is important because one well documented obstacle for students in solving word problems is an interruption, or suspension of sense making (Johnson, 2013). In addition CGI strengthens student number sense and mathematical relationships through the focus on direct modeling and counting stages of development (Carpenter et al., 1999). It also has been found that by using metacognition to discuss thinking processes students learn to value their own ability to learn (Burk 1996).

CGI helps students become more accurate. It has been found that when students use procedures that they have developed or chosen they are more likely to reach accurate answers than other students that use algorithms (Kamii & Dominick, 1998). Even Fyfe et. al., (2014) conceded that students that were allowed to explore math before receiving instruction showed a better understanding of the concept then those that had experienced direct instruction first.

Conclusion

In this chapter we have reviewed literature that addresses the value of problem solving and the skills necessary to be successfully inquisitive. We have been introduced to Cognitively Guided Instruction (CGI), learned about how it addresses the complexities of teaching problem solving and gained knowledge about components of practices including metacognition and cooperative learning. We also have seen the benefits of CGI as well as the drawbacks to explicit instruction.

We also have gotten a glimpse as to why CGI is important to greater society. "Constructivist theory helps us to understand how people learn. With that understanding, we can help to prepare all students to be autonomous individuals who are knowledgeable, resourceful, and responsible members of their democratic society" (Burk, 1996 p. 11).

Our students today will be our caretakers and leaders in the future. We need to foster in our children a balance of independence and responsibility so that they will be able to guide our future society.

CHAPTER 3

Introduction

This study answers the question: *How does using a combination of whole class and small group conversations, along with individual math conferences, impact the rate of growth in problem solving and language development in kindergarten students?* This question is important because although there has been much research regarding Cognitively Guided Instruction (CGI), most of it has been done in older grade levels where classroom teaching methods that require stamina for discussion are more attainable due to age and maturity. This is one of a handful of studies conducted at solely the kindergarten level from a CGI lens. Other studies have found that kindergarteners are able to solve mathematical word problems when using a pencil and paper as their tools (Johnson 2013) and that kindergarteners can solve a wider range of problems than textbooks provide (Carpenter et.al., 1993). More information needs to be gleaned about how to best teach problem solving for this age range, what types of problems are in the zone of proximal development for kindergarten students and the affects of CGI on the language development of kindergarten students.

This study contrasted and compared three trial groups and a control group. The trial groups utilized different frequencies of CGI exposure. This was done so that the frequencies can be compared to one another to see if there is a correlation regarding the amount of exposure to CGI and rate of growth in student problem solving and academic language acquisition. The trial groups also exposed students to different variations of problem types to reveal if a variety of problem types were in the zone of proximal development for kindergarten students. Lastly individual math interviews were conducted and recorded.

Kindergarten is a time when student "conceptions make a great deal of sense, and they provide a basis for learning basic mathematical concepts and skills with understanding" (Carpenter et. al. 1999, p. 1). Kindergarten can be the year that sets a student up for future success or the one where a student begins to stagnate and become set up for additional challenges. The work that is done in kindergarten is experiential; the time spent learning in kindergarten cannot be duplicated. Kindergarten is the time to create a solid foundation for problem solving and to build connections between math in school and prior knowledge of math at home or in the community.

Research Paradigm

The research approach being utilized for this study is Pragmatic. This viewpoint is concerned with practical applications of new strategies and on solving real world problems (Creswell, 2014). The ability of graduating students to think and problem solve at a higher level is very concerning. Today's students will be running the world for future generations. An alarming amount of students are unable to understand how math works;

instead students just memorize a ton of rules to navigate math classes. It is imperative to create a solid mathematical foundation with students beginning at the kindergarten level, so that as students grow older they will not only be able to compute and use short-cuts, but they will also know how to problem solve and be able to explain how mathematical concepts relate to real world problems.

Research Method

A mixed methods approach was used in this study because this type of method is used often to appraise the effectiveness of interventions and programs (Mills 2014). This study evaluates the appropriateness of using CGI to teach mathematical problem solving at the kindergarten grade level. Using mixed methods allowed a combination of qualitative data such as observations collected from math video conferences and class discussions with quantitative data that measures critical thinking and the underlying skills necessary to problem solve. A pre/post test was used to evaluate problem solving ability and development as well as metacognition used by students. Frequency counts of academic language were recorded to see how mathematical conversations impact math vocabulary.

Setting and Demographics

This study was conducted in a kindergarten setting within a K-5 elementary school in an ex-urban community of a large Upper Midwest Metropolian Area. The host district is supportive of CGI practices in mathematics. According to the State's Department of Education, the research site has 37% of students receiving free/reduced lunches during the year of the study, which was the highest percentage within the host district.

Participants

Participants in the study included 28 kindergarteners from 3 classrooms. Students that were 5-7 years of age and had a signed permission were included in the study. All of the students in kindergarten were invited to participate, and 38 students had parent/guardian permission to participate in the study. 7 students were excluded from the study because they had IEP's and 3 more students were excluded due to their status as English Language Learners. This was done to ensure that we were capturing the effect of mathematical conversation in a typical classroom. This left 28 participants from 3 different classrooms.

Methods

Pre-test

Prior to the beginning of the study, all kindergarten students in the three sections were given a pretest using an adapted version of a CGI Developmental Interview that included four problem types: join result unknown, join change unknown, multiplication and separate result unknown. These problem types are described as active because they "involve a direct or implied action" that "takes place over time" (Carpenter et. al. 1999 p.7-8). In addition, students completed District Winter Math Assessments that evaluated number identification, number counting, and number writing.

Experimental and Control Groups

Once the pre-assessments had been conducted students were placed into experimental and control groups. Both experimental and control groups took place in addition to regular math instruction. Regular math instruction occurred for 60 minutes daily using enVisions MATH (Charles et. al., 2011). The first experimental group was Problem of the Day. Problem of the Day took place each afternoon for 15-20min. Students individually tackled a new word problem each day. Following individual work time, the researcher used CGI practices to guide a whole class mathematical conversation. These types of conversations have been shown to "help students deepen their understanding of completed work and connect it to other mathematical ideas" (Jacobs and Ambrose 2008, p. 264). The CGI frameworks were also used to create appropriate word problems for Problem of the Day.

In addition, the entire kindergarten grade level was mixed and split into three weekly groups that met every Friday. This group was labeled Think Math. All three sections taught problem solving in math. Two of the sections were control groups and used enVisions math curriculum (Charles et. al., 2011) which included math stories, math games, introduction to math vocabulary, and the solving a word problem or developing skill sets necessary for problem solving each session.

The third Think Math group also learned about problem solving. However, this group was taught from a CGI lens. The format for the Think Math experimental section was a warm up with a math song, presentation of a word problem, individual work time to solve the word problem, class mathematical conversation, and a subitizing activity.

Students that participated in Video Conferences, from both the Think Math group and the control groups, were recorded directly following Think Math time.

Six students participated in both the Problem of the Day and the Think Math groups. This group became the third experimental group and was labeled Both. These students experienced six episodes (130 minutes) of CGI based practices each week. Problem of the Day experienced five episodes (100 minutes) of CGI based practices each week with one episode in a control group using enVisions MATH (Charles et. al., 2011) curriculum on the fifth day. Five students were in this group. Seven students participated in the once a week CGI-based Think Math group (30 minutes). Ten students were in the control group (0 minutes). (See Figure 2.)

Figure 2 Total Study Participants

Name of Group	Both	Problem of the Day	Think Math	Control
Quantity of students	6 students	5 students	7 students	10 students none (control)
Minutes CGI a week	130 minutes	100 minutes	30 minutes	0 minutes

Video Conferencing Sample Group

Volunteer researchers followed up with 16 students from the grade level with video recorded math conferences; 6 students that were in the Both group, 2 students that were in the Problem of the Day group, 5 students that were in the CGI-based Think Math group, and 3 students that were in the Control group participated in video conferences. Volunteers asked students questions that were adapted for their developmental level from a list of prompts that was developed using knowledge gained from the CGI research.

Research has shown that these conferences may be a critical part of developing knowledge in math (Johnson 2013). Student responses were scored using the Adapted Analytic Scoring Scale based off the recommendations of Charlesworth & Leali (2012) that evaluates problem solving skills and language skills associated with problem solving as well as metacognition. Video conferences were analyzed for problem solving skills and frequency of the use of academic language. (See Figure 3)

Figure 3 Video Conference Participants

Name of Group	Both	Problem of the Day	Think Math	Control
Quantity of students	6 students	2 students	5 students	3 students none (control)
Daily Math Group	Problem of the Day	Problem of the Day	-	Control
Weekly Math Group	Think Math	-	Think Math	Control
Minutes per week	130 minutes	100 minutes	30 minutes	0 minutes

Student data was compiled into four groups. (see Figure 2) The first group received both Problem of the Day CGI discussions and weekly CGI Think Math. The entire group participated in the video math conferences using CGI informed prompts. The next group participated in daily Problem of the Day sessions, but were in the control group for weekly math sessions. The third group did not participate in Problem of the Day but were included in Think Math. The last group contained students that were not exposed to a problem of the day in their homeroom class and also were in the control group for weekly math sessions; essentially students that did not receive CGI. All experimental and control groups were conducted in addition to regular math instruction using enVisions MATH (Charles et. al., 2011) curriculum.

Post-Test

At the end of the research period, all students completed a post-test that evaluated the same four problem types that were presented on the pre-test at the beginning of the study. This was done to monitor growth and rate of progress.

Research Staffing

The researcher lead instruction and facilitated all discussions in the experimental CGI-based groups. The researcher had training in CGI both through a University course as well as through the host school district. The math conferences were recorded and led by trained recruits that underwent a CGI training led by an Instructional Support Specialist before participating in the study. All researchers underwent background checks that comply with the expectations of both the Human Subjects Committee of the University and the host school district policies.

Tools

Tools for this study included both instruments used to assess students and instructional tasks used to teach students. Tools used to assess students included an adapted CGI Developmental Interview and district math assessments. Manipulatives, paper and pencils were provided because research shows that these tools engage students in metacognition and are appropriate ways to assess problem solving in kindergarten (Charlesworth & Leali 2012). All student work was retained and video conferences were kept for review.

Tools used to teach students included word problems that were developed using the CGI taxonomy for routine problems and prompts researchers used during Math Conferences were adapted from Johnson's Word Conference Protocol (2013). In addition, math sheets were created by the researcher and used by students to convey and record mathematical thinking.

Data Analysis

An Analytic Scoring Scale was adapted from "Using Problem Solving to Assess Young Children's Mathematical Knowledge" (Charlesworth & Leali, 2012) and Johnson's 2013 study "Kindergarten Students Solving Mathematical Word Problems". Coding was utilized to compare/contrast the 4 different groups of students that were followed in this study in the areas of problem solving and language. Information was coded so that trends could be identified and groups could be compared. An independent recruit trained by an Instructional Specialist in CGI coded video conference interviews after spending time norming with the researcher for this study. The researcher coded both the pretests and posttests.

Frequency counts of academic language used during the five video conference sessions of the study were compiled and compared/contrasted along with the total words used by students. This was done to see if students experienced changes in the volume and quality of academic vocabulary used as they participated in mathematical conversations.

In addition, observations were recorded throughout the study both on video and in writing through teacher field notes. Observations have been found to be a considerable portion of the types of assessment conducted for kindergarteners (Charlesworth & Leali 2012). It is valuable at this age to use observations because they reveal a lot about a student's understanding. Observations were also used so that unanticipated trends could be addressed.

Summary

This chapter you has covered the methods of this study used to answer the question, *How does using a combination of whole class and small group conversations, along with individual math conferences, impact the rate of growth in problem solving and language development in kindergarten students?* The paradigm has been identified as Pragmatic and the research method used was a Mixed Study with a pre/post test as well as student work samples, field notes collected over the course study period, and video conferences with a cross section of students. The setting has been identified as an ex-urban community of a major metropolitan area in the Upper Midwest and the participants are kindergarten students. This study included three experimental groups and one control group. Whole group instruction and small group instruction using CGI instructional practices along with individual math conferences conducted by trained researchers were utilized in the experimental groups. Tools used within this study have been adapted from previous kindergarten studies and recommendations for best practice in problem solving. This study incorporates data analysis, using coding to create numerical data so that trends could be used to analyze changes in student learning. In addition a cross section of the four groups totaling 16 students have been followed with recorded math conferences. Finally, the Human Research Process identified by the University was adhered to as well as the requirements of the host school district.

In Chapter 4, data compiled from the study including the results from the pretest and the posttest will be presented as well as, frequency counts regarding the usage of academic vocabulary, and notable observations. Data is analyzed and trends are identified by comparing and contrasting the four different groups of students in the study. Finally, in Chapter 5 findings are interpreted so that the research conducted in this study may become applicable to classrooms.

CHAPTER 4

Introduction

The question being addressed with this study is, *How does using a combination of whole class and small group conversations, along with individual math conferences, impact the rate of growth in problem solving and language development in kindergarten students?* This chapter will look at the results of the video conferences, the pretest and post test results, language frequency counts, and observations that were recorded during the course of this study.

Over the course of 10 weeks, from January to May, 28 Kindergarten students were taught mathematical problem solving using three different approaches. The first group was called Problem of the Day and was exposed to Cognitively Guided Instruction practices (CGI) daily for 15-20 min which totaled 100 minutes a week. This group was taught by the researcher. The Problem of the Day group included presentation of a word problem, individual work time to solve the problem, and a whole class discussion where 2 or 3 students shared how they solved the problem, and the class compared and contrasted the different strategies and representations that students utilized. This group was exposed to four different types of word problems: join result unknown, join change unknown, multiplication, and separate result unknown. The next group was called Think

Math and was exposed to CGI practices once a week for 30 min, the researcher also taught this group. The Think Math group followed the same process as the Problem of the Day group except the Think Math group met once a week and had extended discussions that reviewed 3-4 student strategies and included time for self-reflection. The Think Math group was only exposed to one problem type, join change unknown. Some students in the study participated in both Problem of the Day group and Think Math groups, meaning these students were exposed to mathematical discussions 6 times a week for a total of 130 minutes. The control group was the last group. They learned problem solving using enVisions MATH (Charles et. al., 2011) curriculum from their regular classroom teacher.

Figure 4 Group Configurations

Group name:	Both	Problem of the Day	Think Math	Control Group
Taught by:	Researcher	Researcher	Researcher	Kindergarten Teachers
Minutes of mathematical discussions per week:	130 minutes	100 minutes	30 minutes	0 minutes
Number of students:	6	5	7	10

* Of the 62 Kindergarten students, 28 were included in the study. Problem of the Day totaled 19 students of which 11 were included in the study; Think Math totaled 22 students 13 of which were included in the study.
** The number of students in the Both group were only represented in that column which means a total of 11 students were included in Problem of the Day and 13 students were included from Think Math.

The entire grade level took both a problem solving pretest before the study and posttest after the study that included 4 different types of story problems: join result unknown, join change unknown, multiplication, and separate result unknown. The entire grade level also completed district math assessments before the beginning of the study and after the end of the study which included number identification, number counting, and number writing. Students who did not have parent/guardian permission, who received services as English Language Learners and students who received Special Education services were excluded from the study. As such, 28 students from a total of 62 kindergarteners are included in the results. In addition, 16 of the 28 students included in this study participated in video conferences where they were interviewed using CGI practices biweekly throughout the course of the study.

After spending some time norming with the main researcher, an independent researcher, who was trained in CGI by the host school district's Instructional Support Specialist, coded the video conferences using an Adapted Analytic Scoring Scale that was adapted from "Using Problem Solving to Assess Young Children's Mathematical Knowledge" (Charlesworth and Leali, 2012) and Johnson's (2013) study "Kindergarten Students Solving Mathematical Word Problems". (See Appendix A) The main researcher for this study also took frequency counts from each video recording to indicate number of words spoken by the student as well as academic language used by students. Results from the pretests and posttests were analyzed and coded by the researcher for problem solving elements and language development using the Adapted Analytic Scoring Scale. Over the course of the study notable observations during instructional settings were recorded and written work by students was retained.

District Math Assessments

District Math assessments were conducted in January and May. These assessments included having students count verbally, write numbers, and identify numbers. Students verbally counted by 1's, 10's and down from 20 in a one on one setting with school personnel. The students continued to count until they reached district kindergarten goals or they made a mistake. If a student made a mistake in counting the last accurate number counted was recorded. The number writing assessment challenged students to write as many numbers as possible in sequence, from memory using a blank grid similar to an empty hundreds chart. The highest, accurate number in sequence was recorded as their score. In the spring students were offered an additional chart if they wished to challenge themselves beyond one hundred. For number identification students were presented with 108 numbers in non-sequential order and they were asked to indentify as many numbers as possible. The numbers increased in difficulty as the student progressed, if the student missed two complete rows of numbers the assessment was discontinued and the score was recorded.

These assessments are conducted because " children's math achievement at the end of kindergarten is directly associated with their number sense at school entry" (Irwin 2013, p. xi). The school district is able to use number counting, writing and identification to predict student growth and match additional services, like Title I to the students with the greatest need. As shown in Table 1 almost all of the students met grade level goals by May with little variation among the groups.

Table 1 District Math Assessments

Student	Winter					Spring				
	By 1's	By 10's	20 Down	Writes to:	Id (108)	By 1's	By 10's	20 Down	Writes to:	Id (108)
Both										
1E *	65	90	0	59	94	107	100	0	100	108
2E *	100	10	0	100	102	100	100	0	100	108
7E *	100	100	0	100	102	199	100	0	100	103
10E *	100	90	15	49	102	100	100	0	100	105
11E *	58	10	13	30	101	110	100	0	100	108
13E *	109	100	20	29	103	109	100	0	100	107
Average	88.67	66.67	8	61.17	100.67	120.83	100	0	100	106.5
Problem of the day										
9E *	120	120	0	100	108	120	120	0	200	108
12E *	29	10	18	89	18	100	100	15	59	106
4E	69	100	0	64	99	109	100	0	100	108
6E	30	0	20	32	96	100	100	12	100	106
8E	101	100	0	100	107	150	100	0	100	108
Average	69.8	66	7.6	77	85.6	115.8	104	5.4	111.8	107.2
Think Math										
2R *	100	100	0	40	100	100	100	0	35	108
3R	100	100	0	100	100	100	100	0	100	108
5R *	49	100	10	9	92	100	100	0	100	108
12R *	100	100	10	49	99	100	100	0	100	108
4C *	49	100	20	14	15	100	100	10	120	106
7C *	69			100	108	120	100	0	200	108
12C	29	0	20	24	11	69	0	20	100	104
Average	70.86	83.33	10	48	75	98.43	85.71	4.29	107.86	107.14
Control										
4R *	100	100	0	40	100	100	100	0	100	108
6R *	100	100	0	100	100	100	100	0	100	108
11R *	100	100	0	61	100	39	100	0	100	108
1R	100	100	0	79	100	100	100	0	100	108
7R	100	100	10	19	84	100	100	0	100	108
13R	100	100	10	19	19	100	100	0	100	108
3C	110			100	108	200			200	108
5C	100	100	20	100	108	200	100	0	200	108
9C	100	100	0	100	108	200	200	0	200	108
11C	100	100		100	104	100	100	0	200	108
Average	101	100	5	71.8	93.1	123.9	111.11	0	140	108
District end of year goals: students are able to count to 100 by 1's, 100 by 10's, from 20 down to 0, write to 100 and identify 106 numbers.										

Pre/Post Tests

Pretests and posttests were utilized to show any changes in student problem solving and language. 28 students completed a pretest at the onset of the study, during week 1 before problem solving instruction began. At the end of the study, the same 28 students completed a posttest during week 10. The posttest was similar to the pretest, but included slightly larger numbers to account for rate of growth over time. Students completed the pretests and posttests individually without teacher assistance. One problem was completed a day over the course of four days, for both the pretest and the posttest so that student stamina did not affect scores.

Figure 5 Pretest and Posttest Questions

Adapted CGI Developmental Interview for Pre-Assessment.

1. *Join Result Unknown*
Tanner had 3 cookies. Abby gave him 3 more cookies. How many cookies does Tanner have now?

2.*Join Change Unknown*
Mrs. Robeck has 2 class Eagle Feathers. How many more Eagle Feathers does she need to have 5 class Eagle Feathers.

3.*Multiplication*
Mrs. Wills has 3 boxes. There 2 scooters in each box. How many scooters does Mrs. WIlls have?

4.*Separate Result Unknown.*
For snack Feathers brought a bag of 10 grapes. She ate 6 grapes. How many grapes are still in the bag?

Adapted CGI Developmental Interview for Post-Assessment.

1. *Join Result Unknown*
Tanner had 4 cookies. Abby gave him 5 more cookies. How many cookies

does Tanner have now?

2. *Join Change Unknown*
Mrs. Casey has 5 class Eagle Feathers. How many more Eagle Feathers does she need to have 8 class Eagle Feathers.

3. Multiplication
Mrs. Wills has 4 boxes. There 2 scooters in each box. How many scooters does Mrs. Wills have?

4. *Separate Result Unknown.*
For snack Feathers brought a bag of 14 grapes. She ate 6 grapes. How many grapes are still in the bag?

Pretests/posttests were chosen as a form of measurement for this study so that comparisons could be made across a larger sample group and well as within a variety of problem types. This assessment was also closer to what students are used to in a school setting as opposed to the video conferences. This is because student qualms about being video recorded and rapport with researchers were elements of the video conferences that were eliminated in the pre/posttests.

The results of the pretests and posttests were coded using the same Analytic Scoring Scale that was used to evaluate the video conferences to create quantitative data. The same coding was used for the pretests and posttests as the video conferences so that comparisons could be made across the two assessments and because it was based off of a scale that was successfully used in another study that investigated mathematical problem solving ability. All five elements of the adapted rubric were used to calculate a total score for each problem solved (Charlesworth & Leali, 2012).

Students were grouped into four categories: Both, Problem of the Day, Think Math and Control for the pre/post tests

Table 2 Pretest and Posttest Scores

	Join Result Unknown		Join Change Unknown		Multiplication		Separate Result Unknown	
Student	Pretest JRU	Postest JRU	Pretest JCU	Postest JCU	Pretest M	Postest M	Pretest SRU	Postest SRU
Both								
1E *	9	10	10	9	10	9	5	9
2E *	9		7	10	5	9	7	10
7E *	6	9	8	10	5	8	4	10
10E *	2	10	4	9	8	3	8	9
11E *	6	10	3	10	10	10		10
13E *	10	9	8	10	6	9	9	9
Average	7	9.6	6.66	9.66	7.33	8	6.6	9.5
Problem of the Day								
9E *	9	10	10	10	10	10		10
12E *	6	9	8	9	5	8	4	9
4E	9	10	7	10	7	9		8
6E	10	7	8	4	9	9	4	9
8E	9	9	6	9	10	10	6	9
Average	8	9	7.8	8.4	8.2	9.2	2	9
Think Math								
2R *	6	9	8	9	2	4		
3R	6	7	2	3		5		4
5R *	8	9	3	9	6	6		10
12R *	9	9	8	9	8	8		6
4C *	8	9	7	5	10	5	6	6
7C *	10	10	10	9	10	10	10	6
12C	8		6	10		6	3	7
Average	7.86	8.83	6.29	7.71	7.2	6.28	6.33	6.5
Control								
4R *	10	9	6	7		5		8
6R *	9	7	1	9	4	3		
11R *	9	8	8	8	8	3		9
1R	9	5	8	9	6	9		9
7R	6	3	0	3	3	9		5
13R	9	8	4	8		9		6
3C		8		8	8	8		9
5C	10	10	10	9	10	5	9	6
9C	9	8	10	9	10	10	10	
11C	10	9	10	9	10	10	10	8
Average	9	7.5	6.33	7.9	7.37	7.1	9.66	7.5

* Students that participated in video conferencing.
Empty boxes are missing data due to absences or misplaced data.

Observations of Data

Data from this table shows that the Both group increased their average score on all 4 word problem types. The average increased 2.6 points on the join result unknown problem, 3 points on the join change unknown problem, .67 points on the multiplication problem, and 2.96 points on the separate result unknown problem. One student in this group got perfect scores on all 4 posttest questions. The added exposure to join change unknown problem types during Think Math (one day per week) in addition to the exposure to all four problem types in Problem of the Day (five days per week) could explain why the largest growth was on the join change unknown problem. In comparison the smallest growth was on multiplication, this could be because students in this group were exposed to one multiplication problem a week and it was the one problem type that was not also contained in the math curriculum. It also could be because children seem to have a more difficult time modeling multiplication problems (Carpenter, et. al, 1993). The consistent growth of this group in the video conferences as well as the pre/post test validate that this group was increasing in problem solving ability. The consistent growth of this group in multiple areas indicates that mathematical conversations had a positive effect on problem solving ability in kindergarten students.

The Problem of the Day group also showed growth in all four areas, but the rate of growth was smaller in 2 out of 4 problem types. In addition, one of the problem types where the rate of growth was larger was skewed by missing data, so the growth looks larger than it was is reality. The Problem of the Day group's average scores increase by 1 point on the join result unknown, 0.6 points on the join change unknown, 1 point on multiplication and 7 points on separate result unknown. The separate result unknown's average growth was an increase of 4.4 points when the incomplete data was removed. The Problem of the Day group grew more on the multiplication and subtraction problem than the Both group. The Problem of the Day group also started with higher average scores on all of the problem types except separate result unknown. This means that the Problem of the Day group had less room to grow on the three problem types that they scored well on in the beginning and a greater amount of room to grow on the separate result unknown problem, which could help explain why there was so much growth on that one problem type (Wright, 1994). The subtraction unit in enVisions MATH curriculum (Charles et. al., 2011) was also covered during the middle of the study, so it could have impacted results on the separate result unknown problem type .

The Problem of the Day group showed less growth than the Both group on the join result unknown, and the join change unknown problem types. The Problem of the Day group was exposed to the join change unknown problem type 9 fewer times than the Both group over the course of the study, so exposure could have caused Problem of the Day group to grow a smaller amount on join change unknown. In addition, unresolved confusion about the different problem types from lesser exposure could also have impacted the join result unknown problem type.

Data also showed that the Think Math group increased their average score on 3 out of the 4 problem types. The Think Math group's average increased by 0.97 points on the join result unknown, 1.42 points on the join change unknown, and by .17 points on the separate result unknown problem. The largest gain is on the problem type that this group was exposed to during Think Math time, join change unknown. This group's average reverted by .92 points on the multiplication problem. The regression seen with the multiplication problem type may be that the district math curriculum does not address it and Think Math students were exposed to multiplication through the study because they only covered join change unknown. While the Think Math group's average did grow on 3 problem types, their rate of growth is smaller than the Both group and the Problem of the Day on join result unknown and separate result unknown. The Think Math group did show more average growth on the join change unknown problem than the Problem of the Day group. These results make sense because Think Math solely focused on join change unknown, while Problem of the Day and Both groups worked on all four problem types. The effects of math conversations once a week on one problem type still showed positive mathematical problem solving results, but had less impact than the more frequent and varied types of conversations that occurred when students were in the Both group and Problem of the Day group.

The Control group did not do as well as the Both, Problem of the Day, or Think Math groups on the post tests. The Control group's average score decreased in three of the four problem types. This could be from lack of exposure to the mathematical conversations that were occurring in the other two groups which would indicate that the CGI methods used in this study are beneficial for teaching problem solving and that traditional methods could possibly hinder problem solving development. It could also be because the Control group scored so high on the pretests, particularly the join result unknown and the separate result unknown, that they did not have as much room to grow. This would be more plausible if the average scores had declined by a smaller rate.

The Control group did show an average growth on one problem type, join change unknown. The average growth was 1.57 points. This is the same problem type that three of the ten students in the Control group were exposed to during Math Video Conferences. The three students that did participate in the math conferences averaged a growth of 3 points on the join change unknown problem type compared to the 1.8 percentage point growth of those students in the Control group that did not participate in the video conferences and therefore were not exposed to the problem type at all. This shows a significant difference in achievement which supports the idea that the exposure to CGI practices during the video interviews was enough to positively effect problem solving development. This is particularly true when the pretest is taken into account, because these three students scored similarly to the rest of the Control Group on the pretest.

Both the Think Math and the Control groups were missing a significant portion of the separate result unknown pretest data. One of the classroom teachers misplaced the tests and they were not recovered. This affected the scores of 11 students and could impact the data related to the separate result unknown question. Seven other data points were missing due to absences. Missing data was left empty on the graph and averages of groups were calculated to minimize the impact of the missing data.

Video Conference Findings

Video conferences were conducted 5 times over the course of the 10 week study. Three volunteer researchers were trained to conduct CGI interviews by the host district's Instructional Support Specialist at the onset of the study. Each researcher consistently interviewed the same group of students to promote rapport and eliminate variations due to personalities. All researchers asked interview questions from a list of prompts and student responses were recorded.

16 total students were interviewed for video conferences. Six of the students video recorded were in Both group, two were in the Problem of the Day group, five were in the Think Math group and three were in the Control group.

Table 3 Video Conference Results Using Adapted Analytic Scoring Scale

Student	Pretest	Week 2	Week 4	Week 7	Week 9
Both					
1E	9	6	10	6	10
2E	10	10	10	5	10
7E	9	8	5	10	10
10E	0	10	7	6	10
11E	5	10	10	6	10
13E	10	4	5	4	4
Average	7.16	8	7.83	6.16	9
Problem of the Day					
9E *	10	9	9	10	10
12E *	9	4	9	9	10
Average	9.5	6.5	9	9.5	10
Think Math					
2R **	10	10	9	10	10
5R **	3	10	7	6	10
12R **	6	10	10	6	10
4C **	8	8	7	7	10
7C **	10	10	10	8	10
Average	8	8.71	8.71	8	10
Control					
4R	7	7	9	8	10
6R	9	10	8	4	6
11R	7	9	8	6	5
Average	7.66	8.66	8.33	6	7

Video conferences were chosen because the process allowed the researcher to collect both quantitative and qualitative data at the same time. Qualitative observations will be discussed in a later section.

Student responses were coded by a separate trained volunteer researcher using the Adapted Analytic Scoring Scale adopted from Charlesworth & Leali (2012). This scale evaluated different elements of problem solving including executive functioning skills as well as the use of academic language.

Figure 6 Adapted Analytic Scoring Scale

Area	0	1	2
Understanding the Problem	Complete misunderstanding of the problem	Part of the problem misunderstood or misinterpreted	Complete understanding of the problem
Planning a solution	No attempt or totally inappropriate plan	Partially correct plan based on part of the problem being interpreted correctly	Plan could have led to a correct solution if implemented properly
Getting an answer	No answer, or wrong answer based on an inappropriate plan	Copying error, computational error, partial answer for a problem with multiple answers	Correct answer
Academic Language Used	No academic language used	Academic language used incorrectly	Academic Language used correctly and label for answer
Metacognition	Student does not talk about their thinking process	Student talks about their thinking process but forgets parts or unable to communicate the whole process.	Student is able to clearly convey and remember their thinking process.

Observations of Data

One trend that became apparent immediately was that the Both group, as well as the Problem of the Day and Think math groups, scored higher on the last interview than the Control group of students that received traditional instruction. This could be due to the fact that they genuinely improved in problem solving ability and use of academic language due to the instructional approach of CGI based whole class and small group conversations, along with individual math conferences that were the basis of this study. This improvement could also be due to increased exposure to solving word problems.

It is reasonable to believe that these increases in score are related to the instructional approach because when reviewing the data, the Both group also showed increases in their scores on all four post tests compared to their pretests including increases in academic vocabulary. The Both group also started off behind the Control group in some areas of the school district assessments and caught up with the Control group by the end of the study. They all got perfect scores at the end of Kindergarten for number counting and number writing. They also all came within a few points of perfect scores on number identification. The Both group of students was exposed to the greatest amount of CGI based instruction and consequently grew by the largest quantity in all of the areas that we measured which indicates well-rounded growth. A variety of assessments were used so that data could be triangulated to validate the results. This shows that the students truly gained in ability instead of mastering one test or having a really good score due to a fluke of circumstance. The Both group of students showed consistent growth across a variety of measurements.

The Problem of the Day group typically averaged the highest scores on the video conferences excluding week 2. The Think Math group had the highest average score on week 2 and the second highest average scores to Problem of the Day on the other weeks. This could be because the students in The Problem of the Day group benefited from the mixture of approaches to teaching problem solving. All of these students in both the Problem of the Day and Think Math groups were exposed to some CGI practices and some instruction using envisions MATH curriculum (Charles et. al., 2011). It also could be because they were developmentally more advanced in the area of mathematical problem solving. However, grade level data disputes this idea because neither the Problem of the Day group nor the Think Math group averaged the highest scores on number counting, writing or identification.

A factor that might be affecting the Think Math group's scores is that the majority of students in this group were exposed to one problem type, join change unknown, whereas the students in the Both group and the Problem of the Day group were exposed to four different problem types. This reasoning would explain why the Both group and the Problem of the Day group had higher average gains on the posttests even though the Think Math group had higher average scores with the video conferences and on the join change unknown portion of the posttest. All of the video conferences were one problem type, join change unknown, this was the same problem type used in Think Math. In contrast, the pre/post tests evaluated all four of the problem types that the Both group and the Problem of the Day groups were exposed to.

It also became clear that no students received a perfect score every week. This is likely because problem solving requires the ability to simultaneously utilize several skill sets. This study was measuring the student's ability to understand a question, develop an appropriate strategy, compute the correct answer, use academic language, and use metacognition to remember and convey their thinking process. All of the students in the Both group, Problem of the Day group and Think Math groups were able to attain a perfect score at least once over the full course of the study, but none of the students in these groups were able to do it every week because they were simultaneously working on several sets of skills. The scores show that the skills being measured were in the zone of proximal development for kindergarten students because students were able to attain high scores and that they are developmentally appropriate because the skills were difficult enough to require effort to be practiced in combination.

Most students received lower scores on week 7 when compared to other weeks. This could be because when the word problems were developed the researcher increased the numbers each week, culminating to the largest numbers in week 7. The last week was developed to be similar to the pretest for comparison purposes. The number range used in week 7 may have been a bit too large for the majority of students, although while some still got high scores, only 3 of 16 attainted a perfect score on week 7. This also explains why so many students were successful the last week of the study, when the numbers dropped to be similar to the pretest.

Finally, a look was taken at where students in the video conferences were scoring points over the course of the study. In figure 7 the first image shows where points were earned on the pretest and the second image shows where points were earned the last week. B represents points earned by students in the Both group, S represents points earned by students in the Problem of the Day and Think Math groups and N represents points earned by the Control group.

Figure 7 Point Spread Comparisons

Student Pretest Point spread Date_________ Week N- None

B- Both
S- Some
N- None

Area	0	1	2
Understanding the Problem	Complete misunderstanding of the problem BBB	Part of the problem misunderstood or misinterpreted S	Complete BBB understanding of the problem SSSSSS NNN
Planning a solution	No attempt or totally inappropriate plan BBS	Partially correct plan based on part of the problem being BS interpreted correctly	Plan could have led to a correct solution if implemented properly BBBSSSSS NNN
Getting an answer	No answer, or wrong answer based on an inappropriate plan BBBS	Copying error, computational error, partial answer for a problem with multiple answers	Correct answer and correct label for answer BBBSSSSSS NNN
Academic Language Used	No academic BBS language used NN	Academic language used incorrectly S	Academic Language N used correctly BBBBSSSSSS
Metacognition	Student does not talk about their thinking process BBS	Student talks about their thinking process but forgets parts or unable to communicate the whole process. BBSSS NNN	Student is able to clearly convey and remember their thinking process. BB SSS

Student Week 9 Point Spread Date_________ Week _________

Area	0	1	2
Understanding the Problem	Complete misunderstanding of the problem B	Part of the problem misunderstood or misinterpreted	Complete BBBBB understanding of the problem NNN SSSSSSS
Planning a solution	No attempt or totally inappropriate plan B	Partially correct plan based on part of the problem being N interpreted correctly	Plan could have led NNN to a correct solution if implemented BBBBB properly SSSSSSS
Getting an answer	No answer, or wrong answer based on an inappropriate plan B	Copying error, computational error, partial answer for a problem with multiple answers	Correct answer and correct label for NN answer B BBB S SSSSSS
Academic Language Used	No academic language used NN	Academic language used incorrectly	Academic Language BBBBBBN used correctly SSSSSSSS
Metacognition	Student does not talk about their thinking process NN	Student talks about their thinking process but forgets parts or unable to communicate the whole process.	Student is able to clearly convey and remember their N thinking process. BBBBBB SSSSSSSS

One thing that stood out on the point spread comparisons was that all students in the Both group, the Problem of the Day group and Think Math group were able to get 2 points in metacognition the last week. In contrast, over the entire course of the study only one student in the Control group was able to score a 2 in this area and that student only attained a 2 in metacognition during the last week. This indicates that mathematical conversations not only increase math problem solving ability, but also metacognition.

In addition, the points from the pretest week were earned from almost all areas of the rubric, while during the last week points were primarily in the 0 column or the 2 point column which reveals that either students scored 2's and were proficient in the concepts that we were evaluating or they scored 0's and were totally off track. This could be due to motivation, the students scoring 0 points could have been unmotivated during the video conferences and those that scored 2 points could have been motivated to discuss the word problem. It could also indicate that mathematical conversations impacted growth in all the areas measured, particularly metacognition.

Academic Language Frequency Counts

Frequency counts of the total amount of words spoken by students and their use of academic language were taken from the video conferences to see if math conversations increase use of academic vocabulary. For the purposes of this study academic language included kindergarten mathematical vocabulary such as number words, operations, shapes, prepositions and labels for answers. Students got one point for each word spoken or academic word spoken. Students had an unlimited amount time to talk about their answers. Interviewers did not ask a set amount of questions, instead they took cues from the students as to when to end the interviews.

Table 4 Frequency Counts of Academic Vocabulary and Total Words (TW)

	Pretest Academic	Pretest TW	Week 2 Academic	Week 2 TW	Week 4 Academic	Week 4 TW	Week 7 Academic	Week 7 TW	Week 9 Academic	Week 9 TW
Both										
1E	2	9	14	21	18	32	0	0	23	44
2E	14	23	7	16	9	25	21	47	17	32
7E	31	76	14	27	12	16	18	18	17	74
10E	1	13	13	19	14	49	31	46	17	40
11E	11	46	17	26	26	57	19	71	24	60
13E	0	0	6	14	3	22	4	9	7	15
Average	9.83	27.83	11.83	20.5	13.66	33.5	15.5	31.83	17.5	44.167
Problem of the Day										
9E	36	49	12	29	1	1	13	20	9	19
12E	9	17	0	0	26	31	11	17	6	11
Average	22.5	33	6	14.5	13.5	16	12	18.5	7.5	15
Think Math										
2R	2	4	19	22	14	16	28	43	11	25
5R	23	46	21	21	20	38	24	39	24	38
12R	1	1	18	28	3	7	4	7	6	16
4C	0	3	1	1	20	47	24	32	6	16
7C	6	7	15	18	6	7	4	6	15	16
Average	6.4	12.2	14.8	18	12.6	23	16.8	25.4	12.4	22.2
Control										
4R	2	14	13	21	10	31	4	17	2	3
6R	22	92	5	17	7	30	14	26	2	23
11R	19	0	2	4	11	18	1	2	2	12
Average	14.33	35.3	6.66	14	9.33	26.33	6.33	15	2	12.66
* 0 scores mean missing data/student absent										

Observations of data

The Both group increased the average amount of academic language used by about a word a week. This would suggest that daily exposure to mathematical conversations increased student use of mathematical vocabulary. This group had on average 35% higher use of academic words to total words at the beginning of the study and 39.6% average academic words to total words at the end of the study. They increased their average academic words by 4.6 percentage points over the course of the study.

The Problem of the Day group did not have consistent frequency of total words or academic words. This could be due to the small sample size of the group, which only contained two students. It also could be because as the students became more precise they used fewer words. This group did maintain a 40% -60% average of academic words to total words over the course of the study.

The Think Math group had 52% average academic words to total words at the beginning of the study and 55% average academic words to total words at the end of the study. The average gains of academic growth were smaller than those that occurred in the Both group. This would indicate that math conversations increase the use of academic vocabulary even if they occur on a weekly basis, but that daily conversation will increase the rate of growth in use of academic vocabulary by a larger amount.

The Control group started with a larger average of academic language and then decreased over the course of the study. This group had 40 % average academic words to total words at the beginning of the study and 15% average academic words to total words at the end of the study. They decreased academic words by an average of 25 percentage points over the course of the study. EnVisions MATH (Charles et. al., 2011) curriculum used to teach this group has been criticized for lack of integration of topics over the course of a year, particularly at the kindergarten level. Units are taught for a week or two and then the concepts and skills are not revisited. This could explain why the Control group started with a higher amount of academic vocabulary at the beginning of the study and then petered out over the ten weeks. These results suggest a need for consistent exposure to mathematical conversations for academic vocabulary growth.

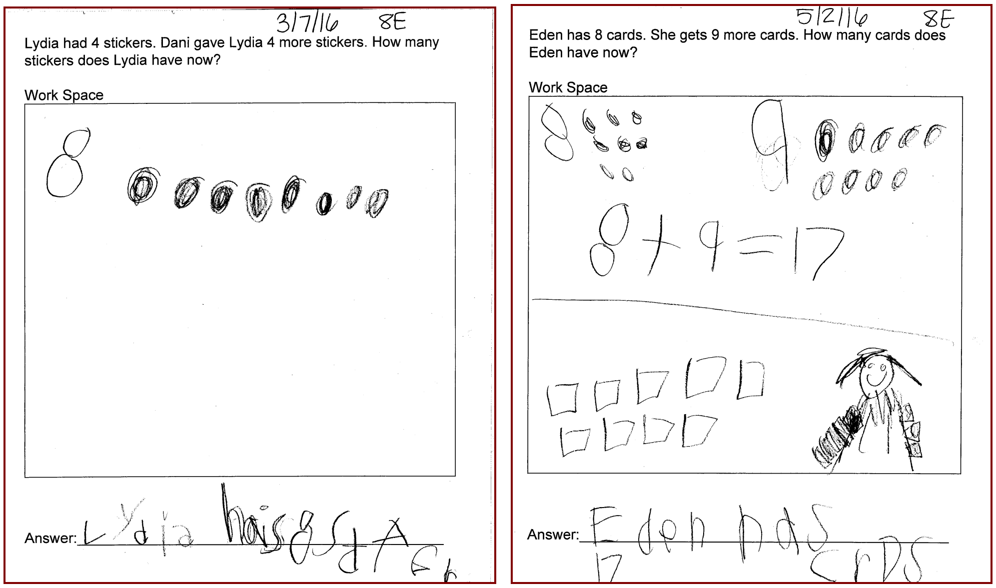
Observations Problem of the Day/Think Math

The last area covered in this study is qualitative data that originated from observations recorded during Problem of the Day, observations from Think Math, and data recorded in written solutions that students completed over the course of this study. Observations were recorded as students shared out their problem solving solutions with the class and on the completed papers that students turned in. Observations were collected so that we could have a comprehensive picture of the effects of mathematical conversations on problem solving and academic language.

In order to locate themes that were notable, notes and records were organized by date. Several recurring themes appeared within the group that was having mathematical conversations. The quantity of strategies that students were using and the manner in which they represented those strategies increased in the Problem of the Day group. The students in the Problem of the Day group also utilized each other's strategies and representations and they would retain new strategies and representations in different settings while the other groups did not. There were some common misconceptions across all groups. Finally trends in growth in metacognition and growth in use of academic vocabulary were apparent.

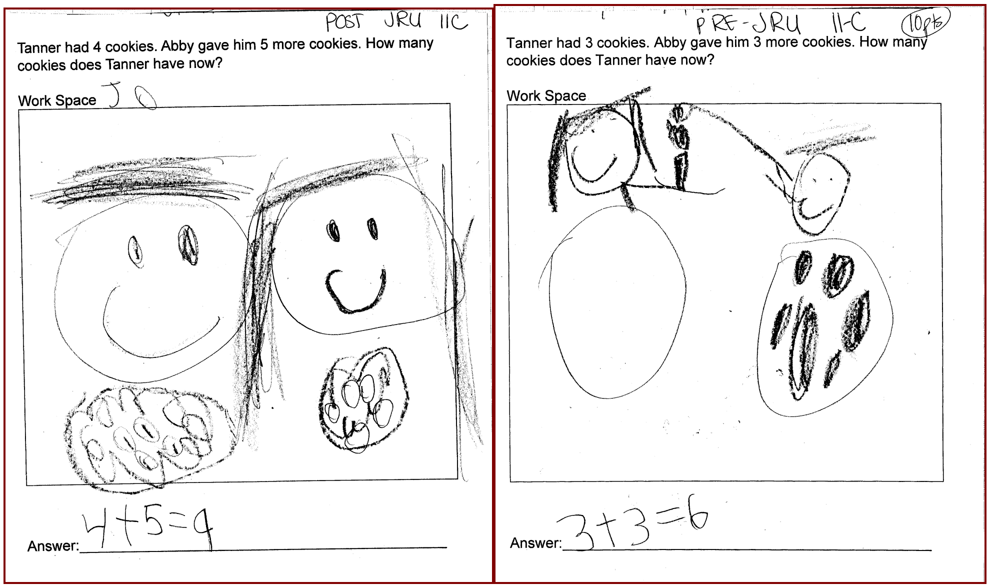
The most obvious theme that observations revealed was that students who were participating in daily mathematical conversations expanded the quantity of strategies that they used to solve word problems as well as their representation of those strategies. On the first day the Problem of the Day group met students only utilized two strategies for solving the problem, they drew a picture of the story and directly modeled the story or they drew dots/numbers to represent how they counted by joining all of the objects. This use of direct modeling is similar to what has been observed in other studies involving kindergarteners and problem solving with CGI (Carpenter et. al., 1993). By the end of the study students were still using direct modeling and counting strategies, but they added more sophisticated counting strategies. Student representations changed too. Students added drawing fingers to communicate how they were counting as well as number lines. They began creating number sentences to practice number facts and circling groups to show direct modeling and counting. This connects to previous studies that have found that, "Over time, children's recordings became progressively more abstract until they were completely symbolic" (Jacobs & Ambrose 2008, p. 265). An example of this is in figure 8 with student 8E, who was in the Problem of the Day group. On the first day student 8E was able get the correct answer with a simple plan; he directly modeled the problem with circles. On the last week of the study student 8E was still able to get the correct answer, but utilized multiple strategies including direct modeling at the top of the page and counting on from the first at the bottom of the page which shows that this student worked through the problem more than once, essentially checking his work.

Figure 8 Problem of the Day Group Comparisons



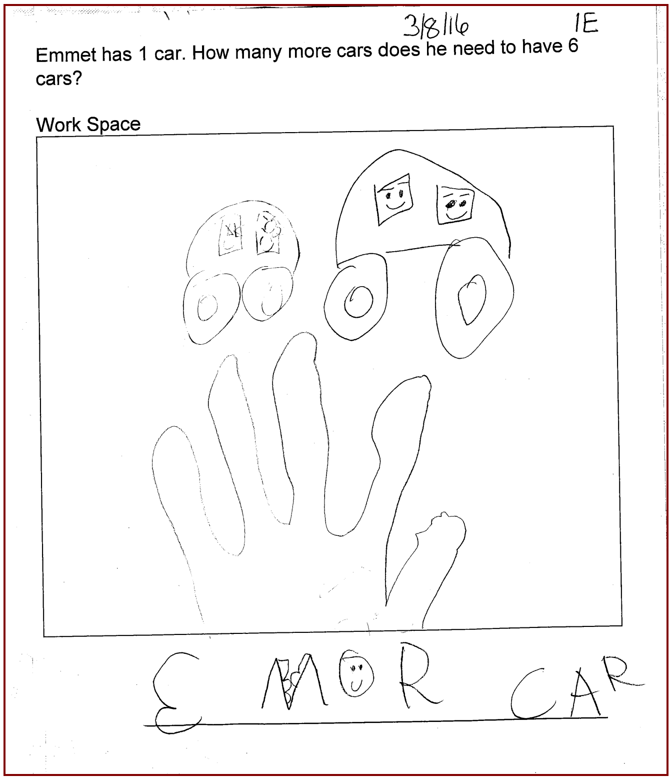
In comparison, students that were in the Control group primarily stuck to the same strategy they used in the beginning of the study. For example in figure 9, student 11C directly modeled the problem on both the pretest and the posttest. The representations stayed similar too. Both the pretest and the posttest show direct modeling to join result unknown. On the pretest the student even draws a line to show the movement of the cookies from one subject to the other. Both representations also include number sentences which were covered in enVisions Math (Charles et. al., 2011) curriculum.

Figure 9 Control Group Comparisons



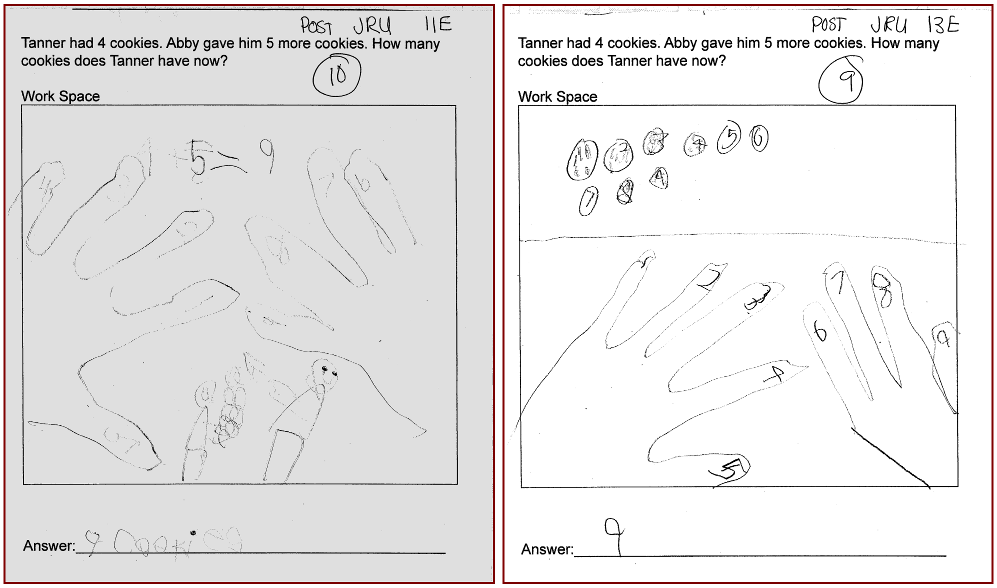
Another theme that emerged in the Both group was that students were utilizing each other's strategies and representations by building on each other's ideas and they were able to carry over new strategies and representations into different settings. For example the first time that a student counted on her fingers and represented it on her paper was on the second day of the study. In figure 10, student 1E drew an outline of a hand to show that a finger counting strategy, counting on from first, had been used to solve the problem.

Figure 10 Counting Representation



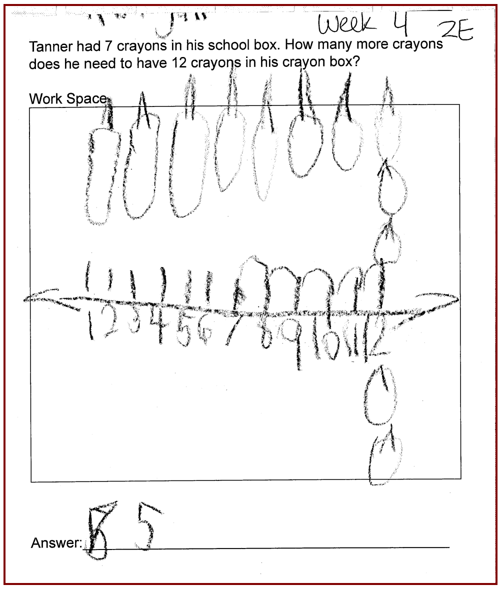
By the end of the study, multiple students in the same classroom as 1E were outlining their hands to represent counting strategies and had added writing numbers on each fingers to show how they were directly modeling or counting to solve the problem. In figure 11 we see two students using this representation for different strategies. Student 11E used fingers to directly model the problem and student 13 E used fingers to count on from larger.

Figure 11 Counting Representations



Another interesting observation is that while students in the Both group were able to use the finger counting representation and evolving strategies in both Problem of the Day and Think Math, other students in Think Math did not pick up this strategy. The students that were in the Think Math group that were not in the Problem of the Day group were exposed to the finger outline representation but utilized representations that they held in common with their homeroom instead. This could be because of the limited exposure the classes had together of 30 minutes a week for Think Math, or because students from the Both group were carrying over multiple strategies and representations. In addition to representing direct modeling and finger counting with hand outlines, students also carried over counting strategies. For example in week 4 student 2E added in using a number line as a new representation and used counting on as a strategy (Figure 12).

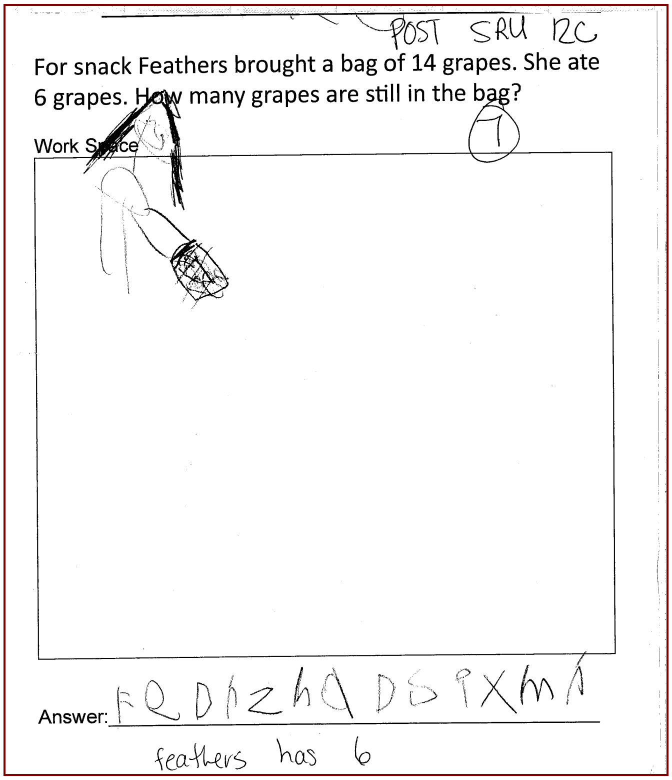
Figure 12 Number Line Representation



This shows that daily exposure allowed students to pick up counting strategies and new representations and also carry them over into new settings, while weekly exposure did not allow students to pick up strategies or representations from one another.

Another theme that observations revealed was that there were some common misconceptions that were specific to the ability to solve a word problem. One problem that occurred was that some students were able to explain their thinking but still get the math wrong. For example on the fourth week of the study, four students were able to explain that they guessed at the answer and two students were able to identify that their strategy did not match the word problem. Yet another student was able to identify that they miscounted. Another misconception was that some students would draw the last thing that they heard instead of making sense of the problem, such as 12C did on the following problem in figure 13.

Figure 13 Misconception


POST SRU 12C

For snack Feathers brought a bag of 14 grapes. She ate 6 grapes. How many grapes are still in the bag?

7

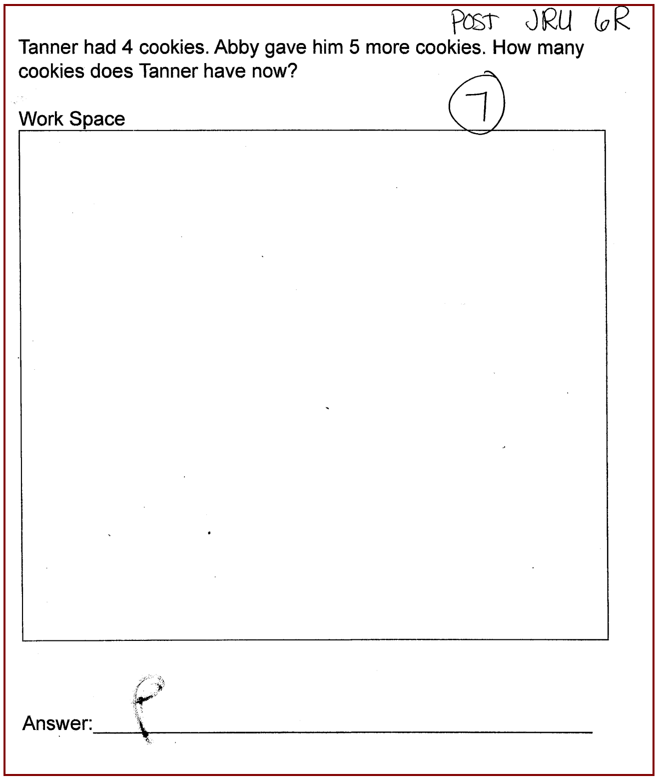
Work Space

Answer:

feathers has 6

These students seemed to understand part of the problem but lack the connection to the actual action included in the problem. Finally, there were students that could get a correct answer, but would be unable to remember their thinking or explain what they were thinking. For example, student 6R was able to find the correct answer to the word problem, although this student does have a reversal, but does not communicate in writing or pictorially at how the answer was arrived at. In addition, student 6R was also unable to communicate how she arrived at answers during the posttest videoconferences. When asked how she got an answer this student would say “I don’t really know anything because that was so easy.”, and when asked if she could draw a picture or use blocks to show what she did she said “I don’t really think so”.

Figure 14 Misconception with Correct Answer


POST JRU 6R

Tanner had 4 cookies. Abby gave him 5 more cookies. How many cookies does Tanner have now?

7

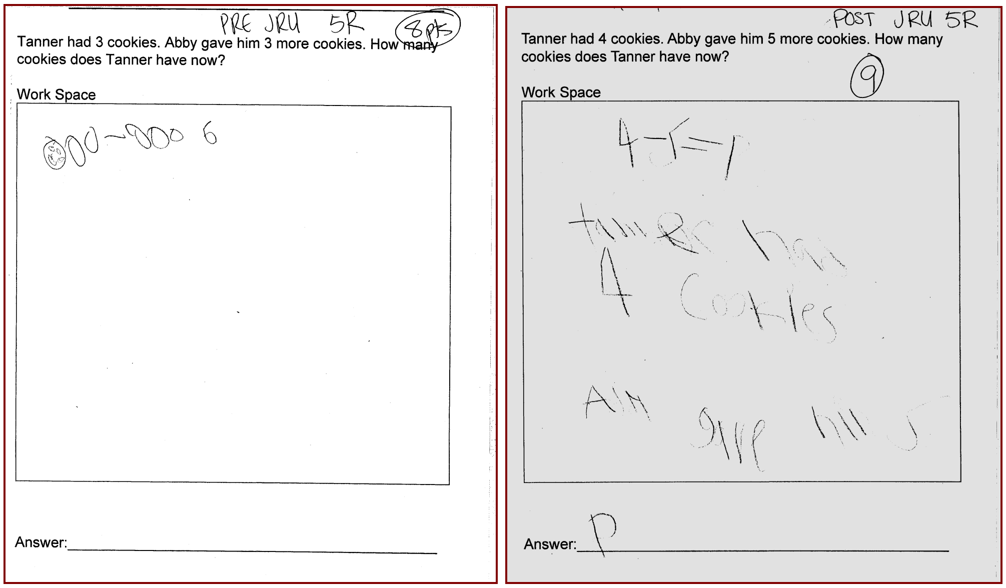
Work Space

Answer: 9

Students also would have work on their paper that showed a strategy and a representation rather than just a number and still be unable to remember or communicate what they had done.

The last notable observation is that the students that participated in mathematical conversations experienced growth in their use of mathematical vocabulary. Students not only began to label answers and use number words, but they also started using words to indicate a mathematical operation, as well as past and present tense. For example in figure 15 student 5R did not use any words on the pretest for join result unknown. On the posttest this student rewrote the problem, using or practicing the mathematical vocabulary.

Figure 15 Academic Vocabulary Growth



Practicing vocabulary not only happened on papers, but also happened as students explained their thinking in class. In the video conferences student 5R was able to communicate her thinking about the join change unknown problem: Mrs. Casey has 5 class Eagle Feathers. How many more Eagle Feathers does she need to have 8 class Eagle Feathers, by explaining how she counted, “I did 1,2,3,4,5 then I skipped 5 and did 6, 7, 8.” She was also able to identify that Mrs. Casey needed “three” eagle feathers and that “ five plus three equals eight”. Students began talking about “counting up” and “groups” in their sharing. By the end of the study, students in the Both group were starting to catch their own and one another’s mistakes too. They would use their new vocabulary to help each other and find their own mistakes. An example of this occurred in student 11E’s video. Student 11E was in the Both group. He started telling how he answered the join change unknown problem previously mentioned, about Mrs. Casey and her Eagle

Feathers, and started telling things out of order, “So I first did my hands on the table and then I writed um (them), and there was five and there was three more. And she (Mrs Casey) first had five and she needed to get to eight so I writed eight, three”, then he stopped and corrected himself,“ So I writed five first and then I writed three more because that makes eight, she already had five so she needed three more.” This student was able to stop the moment he got confused and correct his mistake. These types of occurrences were becoming more and more common in the Both group over the course of the study.

Conclusion of Findings

In this chapter findings from the video conferences, the pretest and posttests, the language frequency counts and notable observations have been covered. Comparisons have been made between the results of students that received the greatest quantity of mathematical conversations, those that had some mathematical conversations and those that did not have mathematical conversations. The findings indicate that CGI based instruction increased problem solving ability and academic language consistently across multiple measurement tools. This data shows that the more often students were exposed to mathematical conversations the greater their rate of learning increased. In the next chapter inferences we can make from this study, the implications that it will have, the limitations of this study and opportunities for further research will be discussed.

CHAPTER 5

Introduction

This study answers the question, *How does using a combination of whole class and small group conversations, along with individual math conferences, impact the rate of growth in problem solving and language development in kindergarten students?* In chapter 4 data was looked at regarding types of growth in problem solving that occurred when students partook in mathematical conversations as well as changes in academic language. The data that was investigated included coding from video math conferences, coding from pre/post tests, frequency counts of words spoken by students and mathematical vocabulary as well as notable observations.

Conclusions

Students who participated in mathematical conversations during CGI based instruction showed the most growth in problem solving ability, metacognition, and academic language use when the conversations occurred daily as opposed to just once a week.

The increase in academic language is similar to Wedekind's (2011) observations of ELL learners who were exposed to daily mathematical conversations. In the beginning of the year she described her ELL learners as communicating with, "more a matter of showing than telling", but by the end of the year, "they were able to communicate their thinking in English through a combination of showing and telling" (p. 123). What we know about language development also explains why daily mathematical conversations were beneficial "One part of basic oral language that has been hypothesized to be especially important for the development of mathematical ability is the language that includes math-related concepts" (Toll and VanLuit, 2014, p. 66). As student's language increased from daily exposure and use, it had a positive influence on mathematical ability. The increase in student use of academic language is explainable because, "Children have an easier time figuring out the meaning of words through personal interaction rather than reading word definitions from a book or paper" (Bruun, Diaz and Dykes, 2015, p. 532). This study revealed that students picked up and maintained academic language better in the groups that used mathematical conversations than those in the control group that were studying vocabulary from papers. The group of students that experienced the most mathematical conversations increased their average use of academic words by 4.6 percentage points over the course of the study while the students in the control group decreased their average use of academic words by 25 percentage points.

The growth of the Both group in problem solving is similar to previous studies that have shown that, "giving children experience with addition and subtraction problem types that are not typically part of the primary mathematics curriculum can significantly improve performance." (Carpenter et. al., 1993, p. 431). In this study the Both group and the Problem of the Day group received instruction with the largest variety of problem types and also showed the greatest improvements in problem solving. Another way that these studies are similar is that Carpenter et al. found that, “Almost 90% (of students) used a valid strategy for the most basic subtraction and multiplication problems, and over half the children were successful on even the most difficult problem” (1993, p. 438). This study found increases in the use of accurate strategies over the course of the study, which was presented with the Point Spread Comparison (Figure 7). District assessments also revealed that mathematical conversations did not hinder growth in skill sets commonly measured at the kindergarten level as all groups had similar outcomes on district assessments (Table 1).

Additionally, it was observed that daily mathematical conversations encouraged students to share and try new strategies and representations to solve word problems while weekly mathematical conversations did not. This, too, is similar to previous kindergarten studies involving problem solving and CGI practices. Carpenter et al. (1993) observed that, “the children in this study did model problems that differed from the problems that they saw in class” (p. 439). Just as the students in the prior study were able to carry over the strategy of direct modeling, the students in this study who practiced mathematical conversations daily were able to do the same. In addition, the students who had mathematical conversations daily were able to pick up each other’s ideas for representing the direct model strategy. This is an extremely valuable outcome because, “Through experiences with multiple strategies children can gain the ability and flexibility to change strategies when one is unsuccessful” (Jacobs and Ambrose, 2008). The capacity to learn new strategies increases a student’s capability to get a correct answer when problem solving and increases mathematical confidence as students are able to reach the correct answer more often.

In contrast, weekly conversations still promoted growth in problem solving and language development but at a lesser rate. This makes sense due to the fact that students had less opportunities to practice problem solving and language skills. It has been discovered that, “Favorable circumstances to provide at-risk children optimal opportunities to improve their knowledge and skills of specific math language include use of clear language by the teacher, meaningful practice in “every-day situations,” and continuous verification on whether children understand the offered language correctly through informal observations rather than formal assessments.” (Toll & VanLuit, 2014, p. 74). The Think Math group did not get constant verification of their understanding of language because of the restriction of time. They also did not get as many opportunities to practice language in the setting of mathematical conversations that were facilitated by this study and as a result the Think Math group still showed gains in problem solving and language development but at a much slower rate of growth.

Finally, the control group where enVisions MATH (Charles et. al., 2011) curriculum was used to teach problem solving gave students the ability to make number sentences, but did not increase problem solving ability or academic language use during a 10 week period. In fact the Control group showed decreases in both problem solving ability and language development. The control group decreased their average use of academic words by 25 percentage points over the course of the study and the Control group’s average score decreased in three of the four problem types on the post test.

Limitations

There are several limiting factors that affect this study. The first of these is the sample size. This study included 28 students, with 16 participating in the video interviews. Although 12 students are enough for a study to be statistically viable using certain analytical techniques including a combination of quantitative and qualitative data and dense sampling, 28 students is still a relatively small sample size (Siegler & Crowley, 1991). The experimental groups were not consistent in size, this was particularly true for the video conferences.

The sample group also lacks diversity. All but three of the participants were Caucasian, and students receiving services as English Language Learners and those with Individual Education Plans were not included in the study in order to simplify the number of variables being analyzed. In hindsight this may have been unnecessary. While data from students in this restricted category cannot be included in analysis, there is enough evidence that further study of this group of students is warranted for documenting positive achievement growth.

The duration of the study is another limiting factor. This study occurred for 10 weeks, which is enough to qualify for Response to Intervention requirements, but is still a relatively short period of time to investigate problem solving and language changes.

Inconsistencies between recruits that conducted the mathematical video conferences and the fact that the Control group and the Problem of the Day group were presented with word problems for the first time during the video conferences while the Think Math group and Both group students had already had exposure to the problems used in the videos should be taken into consideration as well.

The last limitation to this study is the missing data from the separate result unknown pretests due to lost work samples. The absence of those scores skews the data relating to that problem type. Due to the small sample size and the lack of diversity, findings from this study should be limited to the community where the study occurred.

Implications

The school where the study occurred has been inquiring about instructional strategies that increase academic vocabulary and promote problem solving. The observations of an increase in problem solving skills, and academic language for students participating in daily mathematical conversations and those findings in the literature for the practices of CGI based instruction, show that CGI based mathematical conversations have a positive effect on student achievement and as such would be an approach recommended for the host site. In addition the positive results indicate that inquiry into the practice of mathematical conversations in wider kindergarten settings is warranted.

Further Research

The greater educational community could benefit from these findings as well because they indicate several areas for further research. Larger sample sizes and more diverse settings should be investigated to see if the outcomes stay consistent. Longitudinal studies would reveal if problem solving gains and language development gains are retained and if the established trends would continue. Students receiving ELL and Special Education services also need to be addressed in relation to mathematical conversations to see if the positive results found in this study carry over into unexplored populations.

Next Steps

The benefits of using mathematical conversations make it clear that the practices and teaching supported by this study will be implemented within the classroom this year at a deeper level. Inquiry based components of enVisions MATH (Charles et. al., 2011) curriculum will be adapted to incorporate mathematical conversations as a portion of daily math instruction within the classroom as well. It is hoped that other teachers will recognize the successes that are a result of these practices and that mathematical conversations will be implemented in other classrooms.

The research surrounding math and language development and its link to the advancement of problem solving abilities and essential life skills represents a clear call for action. Children need mathematical conversations, not just to balance a checkbook, but also to become rational thinkers that are capable of making positive contributions to society. It is hoped that as CGI is more thoroughly researched and understood the instructional approaches used within CGI will be utilized on a greater scale and as a result children in kindergarten classrooms will begin their educational journey as critical thinkers that can connect academic lessons to the world outside the classroom and are able to trust in their ability to solve problems.

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APPENDIX A- ANALYTIC SCORING SCALE

Analytic scoring scale

from "*Using Problem Solving to Assess Young Children's Mathematics Knowledge*"

(Charlesworth &Leali 2012, p. 381)

Understanding the problem

0: Complete misunderstanding of the problem

1: Part of the problem misunderstood or misinterpreted

2: Complete understanding of the problem

Planning a solution

0: No attempt or totally inappropriate plan

1: Partially correct plan based on part of the problem being interpreted correctly

2: Plan could have led to a correct solution if implemented properly

Getting an answer

0: No answer, or wrong answer based on an inappropriate plan

1: Copying error, computational error, partial answer for a problem with multiple answers

2: Correct answer and correct label for answer