The Effect of Cognitively Guided Instruction on Primary Students’
Math Achievement, Problem-Solving Abilities and Teacher Questioning

by

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A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Education

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ABSTRACT

The purpose of this study is to impact the teaching and learning of math of 2nd through 4th grade math students at Porfirio H. Gonzales Elementary School. The Cognitively Guided Instruction (CGI) model serves as the independent variable for this study. Its intent is to promote math instruction that emphasizes problem-solving to a greater degree and facilitates higher level questioning of teachers during their instructional dialogue with students. A mixed methods approach is being employed to see how the use of the CGI model of instruction impacts the math achievement of 2nd through 4th grade students on quarterly benchmark assessments administered at this school, to see how students problem-solving abilities progress over the duration of the study, and to see how teacher practices in questioning progress. Quantitative methods are used to answer the first of these research questions using archival time series (Amrein & Berliner, 2002) to view trends in achievement before and after the implementation of the CGI model. Qualitative methods are being used to answer questions around students' progression in their problem-solving abilities and teacher questioning to get richer descriptions of how these constructs evolve over the course of the study.
ACKNOWLEDGMENTS

It is difficult to know where to begin in thanking so many individuals for their support in this tremendous learning experience. This dissertation is a celebration of all of you for it would not have been possible without your love, support and guidance in this process. To my wife Danielle, you have endured so many late nights and long weekends of shouldering so many responsibilities to make this possible. I love you and am so grateful to be growing together. Thank you also my daughter Mila for always bringing a smile to my face and inspiring me to continue to want to grow. Dad loves you very much. Thank you to my parents for always making education a non-negotiable and helping my family through this intense phase of our lives to continue our learning. To Gregoria H. Fierro, thank you for the love that you poured into my sub-conscious with your always kind words and care. To Candelario R. Medrano, for your example of strength and messages of pursuing education for the betterment of family.

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Background and Context</td>
<td>4</td>
</tr>
<tr>
<td>Problem</td>
<td>13</td>
</tr>
<tr>
<td>Bloom’s Taxonomy</td>
<td>15</td>
</tr>
<tr>
<td>Purpose of Study and Research Questions</td>
<td>18</td>
</tr>
<tr>
<td>2 LITERATURE REVIEW</td>
<td>19</td>
</tr>
<tr>
<td>Theoretical Perspective</td>
<td>19</td>
</tr>
<tr>
<td>Problem of U.S. Math Achievement</td>
<td>22</td>
</tr>
<tr>
<td>Constructs Related to Problem-Solving</td>
<td>26</td>
</tr>
<tr>
<td>Constructs Impacted by Higher Cognitive Questioning</td>
<td>35</td>
</tr>
<tr>
<td>Arguments Against Higher Cognitive Questioning</td>
<td>42</td>
</tr>
<tr>
<td>3 METHODS</td>
<td>47</td>
</tr>
<tr>
<td>Mixed Methods</td>
<td>47</td>
</tr>
<tr>
<td>Participants and Sampling</td>
<td>47</td>
</tr>
<tr>
<td>The Innovation</td>
<td>49</td>
</tr>
<tr>
<td>Data Collection</td>
<td>58</td>
</tr>
<tr>
<td>Archival Time Series</td>
<td>58</td>
</tr>
<tr>
<td>Student Work Samples</td>
<td>63</td>
</tr>
<tr>
<td>Classroom Videotaping</td>
<td>65</td>
</tr>
<tr>
<td>Teacher Interviews</td>
<td>68</td>
</tr>
</tbody>
</table>
## CHAPTER 4  DATA ANALYSIS AND RESULTS

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classroom Videotaping</td>
<td>75</td>
</tr>
<tr>
<td>Student Work Sample Analysis</td>
<td>80</td>
</tr>
<tr>
<td>Teacher Questioning Survey</td>
<td>88</td>
</tr>
<tr>
<td>Teacher Interviews</td>
<td>91</td>
</tr>
<tr>
<td>Archival Time Series</td>
<td>94</td>
</tr>
<tr>
<td>Dissimilar Cohort Comparison</td>
<td>99</td>
</tr>
</tbody>
</table>

## CHAPTER 5  DISCUSSION

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assertions</td>
<td>101</td>
</tr>
<tr>
<td>Limitations</td>
<td>120</td>
</tr>
<tr>
<td>Implications for Teacher Practice and Policy</td>
<td>121</td>
</tr>
</tbody>
</table>

## REFERENCES

<table>
<thead>
<tr>
<th>Topic</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>APPENDIX</td>
<td></td>
</tr>
<tr>
<td>A  TEACHER QUESTIONING MATRIX</td>
<td>129</td>
</tr>
<tr>
<td>B  RUBRIC FOR STUDENT PROBLEM-SOLVING</td>
<td>131</td>
</tr>
<tr>
<td>C  CODEBOOK FOR CLASSROOM VIDEO TAPING</td>
<td>134</td>
</tr>
<tr>
<td>D  TEACHER INTERVIEW QUESTIONS</td>
<td>137</td>
</tr>
<tr>
<td>E  HIGHER LEVEL QUESTIONING SURVEY</td>
<td>139</td>
</tr>
<tr>
<td>F  TEACHER INTERVIEW CODEBOOK</td>
<td>142</td>
</tr>
<tr>
<td>G  IRB PERMISSION MATERIALS</td>
<td>145</td>
</tr>
</tbody>
</table>
# LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ethnicity Composition of P.H. Gonzales Elementary School 2011-2012</td>
<td>6</td>
</tr>
<tr>
<td>2.</td>
<td>AIMS Performance trends in Reading and Math at P.H. Gonzales Elementary School</td>
<td>8</td>
</tr>
<tr>
<td>3.</td>
<td>Teacher Characteristic Information</td>
<td>49</td>
</tr>
<tr>
<td>4.</td>
<td>CGI Problem Types and Examples</td>
<td>50</td>
</tr>
<tr>
<td>5.</td>
<td>CGI Implementation Timeline</td>
<td>52</td>
</tr>
<tr>
<td>6.</td>
<td>Inventory of Video Recordings</td>
<td>66</td>
</tr>
<tr>
<td>7.</td>
<td>Teacher Interview Inventory</td>
<td>70</td>
</tr>
<tr>
<td>8.</td>
<td>Teacher 2A: Pre to Post Rubric Ratings on Student Work Samples: n = 16</td>
<td>81</td>
</tr>
<tr>
<td>9.</td>
<td>Teacher 3C: Pre to Post Rubric Ratings on Student Work Samples: n = 8</td>
<td>83</td>
</tr>
<tr>
<td>10.</td>
<td>Student Solution Strategy Distribution for n = 47 Student Work Samples</td>
<td>85</td>
</tr>
<tr>
<td>11.</td>
<td>Matrix of Questions Posed Pre to Post Using Bloom’s Taxonomy</td>
<td>85</td>
</tr>
<tr>
<td>12.</td>
<td>Teacher Questioning Survey Analysis</td>
<td>89</td>
</tr>
<tr>
<td>13.</td>
<td>Significance of Differences in Achievement: Actual v. Expected Outcomes</td>
<td>98</td>
</tr>
<tr>
<td>14.</td>
<td>Fall 2010 to Winter 2010 Growth Comparisons</td>
<td>99</td>
</tr>
<tr>
<td>Table</td>
<td>Page</td>
<td></td>
</tr>
<tr>
<td>-------</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>15.</td>
<td>Dissimilar Cohort Growth Comparisons</td>
<td>100</td>
</tr>
<tr>
<td>16.</td>
<td>Teacher 2B: Pre to Post Rubric Ratings</td>
<td>116</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Archival Time Series for Current-Year 2\textsuperscript{nd} Graders from P.H. Gonzales Elementary School</td>
<td>95</td>
</tr>
<tr>
<td>2.</td>
<td>Archival Time Series for Current-Year 3\textsuperscript{rd} Graders from P.H. Gonzales Elementary School</td>
<td>96</td>
</tr>
<tr>
<td>3.</td>
<td>Archival Time Series for Current-Year 4\textsuperscript{th} Graders from P.H. Gonzales Elementary School</td>
<td>97</td>
</tr>
</tbody>
</table>
Chapter 1

INTRODUCTION

During my years as an elementary, high school, and undergraduate student, successful performance in mathematics was often equated to strong intellectual ability and as a predictor for student success. I recount numerous conversations with my own parents, teachers, and high school counselors who touted the importance of math as a pathway into the lucrative careers of medicine, architecture, engineering, astronomy, etc. At these times in my life my real interest was to excel in sports, and as any good student would do, I had an interest in pleasing all of my adult mentors who I just described.

I accepted that the avenue to success and a promising future in a lucrative career would come through being an outstanding math student. I invested hours of my time as an elementary, high school, and undergraduate student in the study of math. In a majority of my years as a student, I brought home A’s in math and believed that I had a firm grasp on the subject. My interest in the study of a mathematics-based field when I entered college was influenced by my beliefs in math success equating to career success. Therefore, I declared my major in engineering. I began my first math class at South Mountain Community College in intermediate algebra, due to a brief lapse in study habits my junior year in high school. I excelled in this course and repeated this success through College Algebra, Trigonometry, Calculus 1, Calculus 2, Calculus 3, and Differential Equations. I pulled A’s in each of these classes and gained a great deal of confidence in my ability as a math student. I believed that my success would
translate into the study of engineering as I transferred to the University of Arizona’s College of Engineering and Mines.

I will illustrate the types of problems that were typical of a sample of Calculus 1 homework. We would learn a lesson on differentiation consisting of problems such as the following:

Find the 1\textsuperscript{st} derivative of the following sets of problems:

1. \( y = 3x^3 \)
2. \( y = 5x^2 + 2x^4 \)
3. \( y = 3x \)
4. The function of a ball being thrown by a pitcher is \( y = 2x^3 + 5 \). What is the velocity of the ball when \( x = 0.0005 \) seconds?

I learned during instruction that the algorithm for finding the first derivative of a function is executed as follows:

1. Multiply the exponent by the coefficient of the function.
2. Subtract 1 from the exponent.
3. Write your new function as the product of the original exponent and coefficient and subtracting 1 from the original exponent.

Following this algorithm, I could consistently arrive at accurate answers to such straightforward problems. For example, I knew that the first derivate of number 1 above was 9x\(^2\), for number 2 it was 10x + 8x\(^3\), and so on.

Then I arrived at the University of Arizona’s College of Engineering and Mines in the Fall semester of 1994. I had a great deal of confidence that I would do well in this field because of my successes in math. I recall going to my first electrical engineering class where the problem that was posed to our class was similar to the one below:
Use Thevenin’s Theorem to find $V_0$.

(Solved Problems, circuits.solved-problems.com/). My questions upon seeing this problem were (1) What is a circuit? and (2) What does $V_0$ mean? As we began to work through the problem in groups, my team members were talking about breaking the circuit and resistors. My next questions were what are resistors and what does it mean to break a circuit? I was not keen on looking entirely lost as my group members seemed to be speaking a common language that they understood, so I did not ask these questions. I went through the next few weeks of this class pretending to understand what was going on. After about a month, my questions were no longer technical ones about what resistors and circuits were. My questions turned into why am I doing this to myself and how do I get out of this? Thankfully, I figured out how to get out of it and find an interest and passion in educational leadership.

Upon graduating from the University of Arizona with a degree in business, I spent a very brief stint in banking where I found it very difficult to stay awake from day to day. I ended up finding my way into education by substitute teaching. Shortly after beginning substitute teaching, my principal at the time heard that I was a former engineering student and approached me about my
comfort level with math. I told him that I was very comfortable with math and ended up eventually getting my teaching certificate. I spent a majority of my teaching career as a middle school math teacher. I came back to the classroom and taught the way that I had learned. My students learned to perform algorithms for solving one and two-step equations for an unknown variable. I carefully designed homework problems that paralleled those that we had worked out together as examples during class that day and de-emphasized the word problems at the end of long textbook sections of algorithmic problems. My teammates and I were puzzled when the math performance of our students were not at the levels that we had hoped for.

I tell this anecdote to set the stage for the focus of this study. This study will focus on an instructional strategy aimed at building the problem-solving capacity of 2nd through 4th grade students at Porfirio H. Gonzales Elementary School. I explore this topic in the hopes that the intervention in this study will better prepare students to learn math for understanding and to apply their mathematical thinking to real-life contexts.

Background and Context

P.H. Gonzales Elementary School is situated in the City of Tolleson in the west valley of Maricopa County. It is a part of the Tolleson Elementary School District, which consists of four elementary schools. It is classified as a Title I school due to having a student population with an 81% free and reduced price lunch participation rate. Additionally, 11% of the student population is classified as English Language Learners (ELL). The ethnic distribution of Porfirio H.
Gonzales Elementary School can be seen in Table 1. Three of the schools are configured as kindergarten through 8th grade. A fourth school is a kindergarten through 6th grade configured school. P.H. Gonzales is the original school in the district. The Tolleson Elementary School District was comprised of a single school since its inception until the 2000-2001 school year. In this academic year, a second elementary school was opened on the campus of P.H. Gonzales Elementary School while the new campus was being constructed. This new school was named Sheely Farms Elementary School and opened its new site during the 2001-2002 school year. In the next three years, two more schools were opened due to climbing enrollment as a result of the rapid west valley expansion characterized by the late 1990s and early 2000s.

Prior to the opening of three new schools in our district between the years 2000 and 2005, P.H. Gonzales Elementary School was formerly known as Tolleson Elementary School. It was the only school in the Tolleson Elementary School District. P.H. Gonzales Elementary School has a rich history in regards to civil rights activity to desegregate a school district that has historically serviced a largely Hispanic population. Porfirio H. Gonzales was a resident in the City of Tolleson. In collaboration with a number of local citizens, Mr. Gonzales was a part of a movement to desegregate the Tolleson Elementary School District (personal communication). The school district was comprised of two campuses with one campus servicing white students and the other servicing minority students, primarily Hispanic, for a period of time. Mr. Gonzales signed the lawsuit in Gonzales et al. v. Sheely et al. in 1950 to desegregate Tolleson
Elementary School. The courts ruled in favor of the plaintiffs in the Gonzales v. Sheely case in 1951 on the basis that segregated facilities violated the 14th Amendment Equal Protection Clause, ordering the desegregation of Tolleson Elementary School (Goddard, 2005). Tolleson Elementary School was renamed Porfirio H. Gonzales Elementary in 2000 in honor of Mr. Gonzales and the activists who courageously opposed segregation of children in schools.

P.H. Gonzales Elementary is a kindergarten through 8th grade configured school classified as a Title I school due to its high percentage of students on free and reduced priced lunch. There are 938 students enrolled in the school with 491 boys and 447 girls. The ethnic distribution of the student body is demonstrated in Table 1.

Table 1

<table>
<thead>
<tr>
<th>Ethnic Group</th>
<th>Percentage Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asian</td>
<td>0.5%</td>
</tr>
<tr>
<td>Black</td>
<td>3.7%</td>
</tr>
<tr>
<td>Hispanic</td>
<td>89.8%</td>
</tr>
<tr>
<td>Native American</td>
<td>0.9%</td>
</tr>
<tr>
<td>White</td>
<td>4.8%</td>
</tr>
</tbody>
</table>

The school received a designation of Underperforming in the 2001-2002 school year when the labeling system federally mandated by No Child Left Behind first went into effect. As a result of this designation and the school’s classification as Title I, P.H. Gonzales Elementary was awarded a Reading First
federal grant beginning in the 2003-2004 school year and extending through the 2007-2008 school year.

As recipients of this grant, funds were utilized to hire a full time reading coach, reading interventionists, and the adoption of a scientifically research-based reading program as prescribed by the federal grant. The Reading First grant was also accompanied by ongoing monitoring and support to ensure that implementation to the highly scripted Houghton-Mifflin Reading Program was being followed with strict fidelity and that student progress on the Dynamic Indicators of Basic Early Literacy Skills (DIBELS) were being frequently monitored. Fidelity to the reading program was defined as teachers following the program page by page to ensure that standards-based objectives in reading were being addressed by teachers. Initial increases in reading achievement were realized through the systematic attention given to this subject matter through Reading First. P.H. Gonzales Elementary received a *Performing Plus* performance label and *A+ School of Excellence* designation in the 2005-2006 school year. Student achievement in terms of the percentage of students meeting or exceeding standards on Arizona’s Instrument to Measure Standards (AIMS) went into the low to mid-50 percentile marks in reading. Additionally, students’ fluency levels based on DIBELS measures in kindergarten through 3rd grade were seeing significant improvements.

These initial achievement gains halted over the next two years. Student achievement at P.H. Gonzales Elementary and across the Tolleson Elementary School District struggled to increase the percentage of students meeting or
exceeding standards in reading and math on the AIMS test beyond 50 to 55%.

Table 2 illustrates AIMS performance trends in reading and math since 2006 at P.H. Gonzales Elementary School. This concern prompted our district to engage in a consultative relationship with Solution Tree with the focus of increasing student achievement by improving the ability of teacher teams to work collaboratively as professional learning communities focused on student learning (DuFour, DuFour, & Eaker, 2008).

Table 2

<table>
<thead>
<tr>
<th>Subject</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
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<tbody>
<tr>
<td>Reading</td>
<td>52.0%</td>
<td>52.0%</td>
<td>53.0%</td>
<td>58.0%</td>
<td>71.6%</td>
</tr>
<tr>
<td>Math</td>
<td>56.0%</td>
<td>52.0%</td>
<td>63.0%</td>
<td>66.0%</td>
<td>48.6%</td>
</tr>
</tbody>
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*Note: Numbers in the table represent the percentage of students in the Tolleson Elementary School District who met or exceeded state standards on the AIMS test.*

The years of focus on reading instruction through the Reading First grant left several issues needing attention. First of all, program fidelity and improved reading fluency were the measures observed to evaluate success. Program fidelity translated into how well teaching staff followed the prescribed reading program as laid out in the textbook series. The focus on program fidelity left the evaluation of the quality of instructional rigor largely unaddressed. Reading fluency focused on speed of reading with less emphasis on comprehension of what was read. Secondly, math instruction did not get the same systematic attention as did the subject of reading.
Our S.T.E.M. (Science, Technology, Engineering and Math) Initiative

The recognition to provide systematic support in the area of mathematics instruction was widely acknowledged among the administrative team in the Tolleson Elementary School District. Stagnating trends in mathematics achievement suggested an urgent need within the unfolding context of our education system where college and career readiness is being promoted as a national ideal for all students.

Towards the conclusion of the 2010-2011 school year, our school-district Superintendent began to express our data driven need to pursue a systematic approach to improving math pedagogy and consequently, achievement results in the areas of science and math. It was widely agreed upon that a system-wide initiative was appropriate to address this need from the Governing Board level to the school site level. Community members on my school site council team while I was the principal at P.H. Gonzales Elementary School had also recognized and voiced this need when we would analyze achievement data for our school. In April of 2011, the Governing Board approved for the posting of a S.T.E.M. Director position as well as four S.T.E.M. Coach positions to provide the needed support to improve the mathematics and science achievement of our students.

I was fortunate to be selected as the S.T.E.M. and Assessment Director for the Tolleson Elementary School District for the 2011-2012 school year. As an administrative team, we agreed that the S.T.E.M. Initiative needed to be far-reaching providing support to all of our students from kindergarten through 8th grade. We chose to focus our S.T.E.M. efforts on the area of math placing
emphasis on grounding mathematics instruction in frequent problem-solving opportunities for all students. This is consistent with what the National Council of Teachers of Mathematics (NCTM) promotes as well as what takes place in the highest achieving countries in the area of mathematics (NCTM, 2006). Members of our Curriculum and Instruction (C & I) team had experience with using the CGI model, and we agreed that this framework provided the problem-solving focus that we wanted to promote across all schools and grade levels.

Our Broader Context

A formidable force that heavily influences our context as educators is the privilege ascribed to quantitative outcomes as measures for teacher, school and academic program effectiveness. The passage of the No Child Left Behind Act in 2001 required states who receive federal funding to provide all students with a high stakes test as a measure of their degree of mastery of agreed upon standards in the areas of reading, writing and math. Since the passage of this landmark legislation, the importance attached to quantitative outcomes of students on high stakes tests has gained significant momentum. In the state of Arizona, teachers can earn or not earn performance-based pay according to the attainment of academic goals that students achieve on district and state tests. In the midst of our economic crisis which has penetrated all facets of our society, our federal government has provided opportunities to states, and in turn, school districts to receive additional funding through the Race to the Top initiative. In applications for these significant supplemental funds, it was incumbent on states to show that teacher and administrator evaluation systems were being revised. Key to these
revisions is that a significant percentage of teachers’ and administrators’ outcomes on evaluations are based on the achievement level of students on quantitative assessments.

Our district is also in the midst of implementing a revamped teacher evaluation instrument. In response to state legislation requiring that 33% to 50% of teacher evaluation outcomes is to be based on student achievement outcomes, the Tolleson Elementary School District joined an alliance of six total school districts in the Rewarding Education in Instruction and Leadership (REIL) grant opportunity in the 2010-2011 school year. The work in this alliance involved engaging stakeholders throughout all alliance schools to provide input into a revised learning observation instrument, which serves greater purposes than a mere teacher evaluation tool. The intent behind the learning observation instrument is to provide teachers with guidance around best instructional practices that can contribute to the improvement of teaching and learning system-wide. Semantics matter in this initiative as the new tool is referenced as a learning instrument as opposed to an evaluation instrument. Our engagement in this initiative has great implications for teacher professional development and practice as this new guide becomes the foundation for governing teacher development and performance.

A peek into the window of this contextual factor is important in this study. A key focus of this study is to influence teaching practice so that it becomes more rooted on providing frequent problem-solving opportunities for students. As will be revealed in the literature review, high performing countries on international
measures of mathematics achievement have instilled habits of problem-solving by making math instruction based on frequent and rigorous problem-solving opportunities the norm in classroom instruction. Furthermore, student achievement outcomes have acquired the status parallel to profit margins in private industry. While frequent student achievement checkpoints are important to inform our instructional practices as educators, they fall short of being a worthwhile end in isolation. Dewey (1916) makes the compelling case that growth and learning are ends in and of themselves and how externally imposed ends do not necessarily inspire a desire for learning. Beyond preparation for performance on high stakes testing situations, frequent opportunities to problem-solve generalize to both academic and life situations that students can apply in their chosen endeavors; both current and in the future. The current contextual setting of education diverges from this ideal where the externally imposed end of achievement scores serves the function of rewarding and punishing students, and educators and schools for either meeting or falling short of established measures. This, in turn, influences practice at the classroom level, commonly by way of teachers believing that they have to cover the standards which are largely written as a listing of discrete skills whose connections are not obviously established or articulated. It is within this context that this study unfolds and negotiations between traditional and more student-centered pedagogy promoted by the intervention in this study take place.
The Role of the Researcher

My role as the researcher in this study is an important contextual factor. The school in which the study was conducted is where a vast majority of my experience as an educator has taken place. In the 2004-2005 school year, I was the assistant principal of P.H. Gonzales Elementary School. From 2006 to 2011 I was the school’s principal. From 1997 to 2004 I was also a middle school teacher at P.H. Gonzales Elementary School. My role in a supervisory position with several of the participating teachers had the potential to influence teacher perceptions of the training and its implementation. It was important to communicate to the teachers that my role in the study is entirely non-evaluative, and that I was conducting the research as an independent student outside of the school system. Even while articulating this throughout the study, there was no guarantee that my role would not have an influence on teacher behavior in this study.

Problem

Our school’s mathematics achievement at Porifirio H. Gonzales Elementary School has shown a stagnating trend on our state Arizona’s Instrument to Measure Standards (AIMS) test. Math problem-solving and reasoning are also skills that our students struggle with in their math education. Our results on quarterly benchmark assessments in math also show stagnating and backsliding trends in achievement. The Galileo benchmark assessment which all of our 1st through 8th graders take consists of many problem requiring students to apply math reasoning skills to problem-solving scenarios. Teachers in our school
have shared concerns about students’ struggles with math problem-solving and a lack of persistence when encountered with challenging problems. Analysis of student work samples and their approaches to solving problems also reveal that students frequently perform operations in a problem to arrive at a solution without truly understanding the question being asked. Our collective responses as educators to such situations also reveal a need for professional development to guide students towards acquiring mathematical understandings in contextual situations.

Our problems in math achievement and problem-solving abilities are a microcosm of a much larger national problem with mathematics education. Math education in the United States is prone to favoring algorithmic methods and fact memorization (Darling-Hammond, 2010). This practice also runs counter to what is done in higher achieving nations such as Japan and Singapore where instruction is designed to promote complex problem-solving and math reasoning (Darling-Hammond, 2010). The Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development (2000) corroborated these findings in their report on the underrepresentation of women, minorities, and people with disabilities in science, engineering, and technology (SET) professions. They trace a variety of societal factors contributing to such underrepresentation including inadequate precollege education, access to higher education, poor professional life conditions, and poor public images of these groups in SET fields. (Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology
Development, 2000). Inadequate precollege education is a major focus of this study and is characterized by students having poor access to well-prepared teachers in science, engineering, and technology based instruction (Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development, 2000). The problem of women, minority, and disabled students’ access to well-prepared teachers and persistent practices of tracking are key deterrents to participation of these groups in SET fields (Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development, 2000). This study will explore the problem of math achievement at our school and our students’ struggles with engaging in challenging problem-solving tasks. A secondary problem explored in this study will be the level of questioning that teachers pose during instruction. It will be shown in the literature review that a relationship does exist between the level of questions posed to students in instruction and problem-solving and critical thinking abilities. This study will describe the Cognitively Guided Instruction model for primary math instruction and how it will be used to address the problems highlighted in this study.

In his *Taxonomy of Educational Objectives*, Benjamin Bloom (1956) classifies educational goals into six categories reflecting progressively more complex levels of cognition. Part of this study applies these categories to teacher questioning in primary math instruction. The first level, and least complex in terms of cognitive demand on students, is the *knowledge* level. Bloom describes this level as the direct recall of information for no greater purpose than
remembering facts. The levels of cognition then proceed in a rank order in the following fashion: *comprehension, application, analysis, synthesis, and evaluation*. Bloom describes each successive level in the following manner.

*Comprehension* is a lower level of understanding where students know the material communicated, can use it in simple situations, but cannot necessarily relate it to other material. *Application* is the ability of a student to use an abstract concept in a particular situation. *Analysis* is the student’s ability to break a topic down into its parts. For example, a student may describe the components of a rectangle as consisting of four connected line segments with four vertices.

*Synthesis* describes a student’s ability to bring component parts of a topic into a coherent whole; similar to piecing together a puzzle. Finally, *evaluation* involves a student’s ability to make a judgment about a phenomenon or topic (Bloom, 1956). It is acknowledged in the research and literature that the higher cognitive domains of Bloom’s classification levels reside in the skills of *analysis, synthesis, and evaluation* (Caulfield-Sloan & Ruzicka, 2005; Newton, 1978).

**Infrequent Practice with Higher Cognitive Questioning**

High stakes tests such as quarterly benchmark assessments often contain items requiring higher levels of cognition. This makes it necessary to provide students with frequent opportunities to respond to higher-level questions to set them up for success on such tests (Darling-Hammond, 2000; as cited in Caulfield-Sloan & Ruzicka, 2005). Noted in the literature is how the frequency of teacher questions disproportionately come from the *knowledge, comprehension, and application* levels of Bloom’s Taxonomy (Gusack, 1967; O’Flahavan, 1988;
Williamson, 1996; as cited in Caulfield-Sloan & Ruzicka, 2005; Smith, Rook, & Smith, 2007) and how learning activities are reflective of the lower levels of cognition (Westwood, 1993).

I collected preliminary evidence to further substantiate the need to investigate this educational problem. In an administrative meeting on October 5, 2010, it was unanimously acknowledged in the analysis of first quarter benchmark data that math instruction had not received the systematic attention that reading has over the past several years as described in the introduction of this proposal. Additionally, I developed some rudimentary data collection instruments to gauge the level of questions based on Bloom’s Taxonomy that our teachers are posing in classroom instruction, specifically in 1st through 4th grade math. I received permission from the 1st through 4th grade teachers at P.H. Gonzales Elementary to videotape a segment of their instruction for purposes of conducting this research. I engaged in a process of categorizing the questions posed during these segments of instruction with the corresponding Bloom’s Taxonomy level. This categorization exercise was carried out in collaboration with a panel of five well-respected curriculum experts from within our district to reliably categorize the questions being posed during instruction. The resulting data substantiated the need to further investigate the phenomenon of the cognitive level of questions posed during instruction. The questions posed during four segments of math instruction were analyzed consisting of a total of 102 questions. Only 11 of these questions were judged to be at the comprehension level of Bloom’s while the remaining questions were all categorized as knowledge level questions.
Purpose of Study and Research Questions

The purpose of this study is to provide 2\textsuperscript{nd} through 4\textsuperscript{th} grade teachers at Porfirio H. Gonzales Elementary School with an ongoing professional development program that will promote a problem-solving based approach to math instruction and to develop their use of higher order questioning during math instruction. Literature abounds regarding the need to develop 21\textsuperscript{st} Century Learners whose competencies include the ability to problem-solve. The professional development model, which will be taught to our 2\textsuperscript{nd} through 4\textsuperscript{th} grade teachers, is called cognitively guided instruction (CGI) and is based on providing students with frequent opportunities to engage in math problem-solving in contextual situations (Carpenter, Fennema, Franke, Levi, & Empson, 1999).

The research questions that this study is focused on answering are as follows:

- What impact does CGI have on math achievement results of 2\textsuperscript{nd} through 4\textsuperscript{th} grade students?
- What impact does CGI have on problem-solving abilities of students?
- What impact does CGI have on the level of questioning posed by teachers during instruction?
Chapter 2

LITERATURE REVIEW

The theoretical framework for this study is based on ideas of a combination of theorists. Teacher practices in math instruction have been shown on a national level to reflect algorithmic approaches at the expense of deep understanding (Darling-Hammond, 2010). As a former school principal privy to a vast amount of informal data from frequent classroom visits, it is common to see approaches to math instruction highly focused on algorithmic steps similar to the anecdote described at the outset of this study. International comparisons have shown that this is a national problem where United States teachers are more prone to this style of teaching, whereas higher performing nations tend to place a greater emphasis on less content coverage and greater math reasoning and problem-solving (Darling-Hammond, 2010; Stevenson & Stigler, 1992). Freire’s (1993) views on banking education versus problem-posing education, and Cuban’s (1993) characterization of the student-centered to teacher-centered continuum provide the framework for this study.

*Freire’s Notion of Banking and Problem-Posing Education*

The implications for U.S. student achievement in mathematics of teacher-centered approaches to instruction (Cuban, 1993) are well documented on international comparisons with other industrialized nations (Darling-Hammond, 2010; Stevenson & Stigler, 1992). At yet a deeper level is the concern for what these achievement indicators imply economically and societally for our future leaders. The economic growth being experienced in East Asian and European
nations are being sparked by advances in science and technology while U.S.
students are trending towards the bottom in international comparisons of math and
science achievement in industrialized nations (Darling-Hammond, 2010, p.3).
This trend projects a labor shortage of nearly 7 million jobs in science and
technology by 2012 if it persists (Darling-Hammond, 2010, p.3). Furthermore,
life and citizenship skills in the 21st century demand the ability to frame,
investigate, and solve problems with a variety of tools, and to develop new
products and ideas (Darling-Hammond, 2010, p. 2).

U.S. students are largely exposed to instruction in mathematics that would
be characterized as “teacher-centered” (Cuban, 1993, p. 7). Characteristics of this
type of approach to instruction include a higher ratio of teacher to student talk, a
heavy reliance on the textbook to guide instruction, and the teacher controlling
what is taught (Cuban, 1993, p.7).

This description of teacher-centered instruction lays the foundation for the
theoretical framework of this study. Freire (1993) contrasts curriculum as a
dichotomy with “banking education” at one pole and “problem-posing education”
at the other. He characterizes the former based on assumptions about the
teacher’s role, student’s role, teacher-student interaction, and modes of
instructional delivery. He describes the teacher’s role in banking education as the
knowledgeable expert who presumes the absolute ignorance of the student. In
turn, the student’s identity in this model is one of an empty receptacle that needs
to be filled by the teacher expert. This “teacher-student contradiction”
necessitates instruction where the teacher teaches and the student is taught; the
teacher is the subject of learning, and the student is the object (Freire, 1993, p. 73). Students are expected to accept narrative instruction that is detached from student experience and perpetuates an oppressive society (Freire, 1993, p. 73). The perpetuation of such a society occurs by the good student retaining the details of the teacher’s narration with a resulting suppression of the “critical consciousness” that is essential to students being transformers of their world (Freire, 1993, p. 73).

By contrast, problem-posing education operates from entirely opposite assumptions. Under this curriculum, the teacher-student contradiction ceases to be a reality as teachers and students engage in mutual learning from one another through their dialogue (Freire, 1993, p. 80). Students are now “critical co-investigators” in their learning through dialogue with their teacher (Freire, 1993, p. 81). Students no longer receive instruction in the form of their teacher’s narration. Instead, they are posed real-life, and relevant problems that challenges their thinking. As active learners, rather than passive recipients of narration, they feel obliged to respond to their challenge (Freire, 1993, p. 81). Furthermore, problem-posing education values creativity, reflection, and action to transform a reality, which is viewed as dynamic with individuals as yet incomplete, and still becoming (Freire, 1993, p. 84). The dynamic nature of reality and the incomplete being necessitate a view of education as an ongoing process rather than a final product (Freire, 1993, p. 84).

The application of Freire’s notion of banking and problem-posing education to this study is important. Our nation’s lagging math achievement
internationally would probably not be the most pressing issue in Freire’s perspective as his work spoke much more to the oppressive methods of the power structure that packaged low-quality curriculum to maintain an imbalance of power for the domination of the oppressor. However, the connection of this framework to the need to prepare all students for success with 21st century skills is a laudable goal with important implications for our children’s future.

*The Problem of U.S. Mathematics Achievement*

*A History of Concern*

Trends in U.S. mathematics education have shown concerning results. A national outcry over our ill-prepared students in math was echoed throughout the 20th Century. The Soviet Union’s launching of Sputnik in 1957 caused the United States to examine the quality of its mathematics education on a national level with a call for more inquiry-based pedagogy to improve students’ thinking skills (Hersh, 2009). These concerns persisted into the latter portion of the century when the National Commission on Excellence in Education labeled the United States as *A Nation At Risk* due to our poor standing on international comparisons on academic measures (Office of Educational Research and Improvement, 1997). This report on the poor standing of our education system was followed by the adoption of the 1989 National Goals for Education which proclaimed that the United States would be number one internationally in mathematics and science achievement by the year 2000 (Office of Educational Research and Improvement, 1997).
The goal of attaining first place status in mathematics and science achievement on international comparisons continues to be elusive. A study comparing the achievement of U.S. math students with other countries in the 8th grade and 12th grades revealed that average students in other countries learned more math than the best U.S. math students (Stevenson & Stigler, 1992). More specifically, data from the Second International Mathematics Study revealed that the top 5 percent of students in terms of math achievement match the 50th percentile of Japanese students. More recent international studies demonstrated the need for growth to attain ambitious goals as set forth by the 1989 National Goals. The Third International Mathematics and Science Study (TIMSS) reported how participating U.S. 8th graders in 1995-1996 ranked below international averages of the 41 participating countries (Office of Educational Research and Improvement, 1997). U.S. 4th graders ranked higher in this international comparison being above the international average in math (Office of Educational Research and Improvement, 1997). Results of the Third International Mathematics and Science Study (TIMSS) also revealed that of the 41 participating countries in the study, twenty of the nations scored significantly higher than the United States while only seven scored significantly lower (Stigler & Hiebert, 1999, p. 6). U.S. rankings in a more recent international assessment conducted by the Program in International Student Assessment (PISA) showed U.S. students ranking 25th out of 30 countries in mathematics, representing a drop from 3 years earlier (Darling-Hammond, 2010). These national trends are
consistent with the local math achievement trends that are being examined at Porfirio H. Gonzales Elementary School.

*The Importance of Mathematics Achievement and Problem-Solving*

Advancing the mathematics achievement of U.S. students has been a long-standing effort. The aim of improved mathematics achievement is important on many levels. One highly debated level is our students’ ability to perform well on high stakes tests. The passage of No Child Left Behind instituted a culture of accountability through high stakes testing that has swept our nation. Rewards and sanctions have been attached to achieving well on high stakes tests including receiving college scholarships and being granted promotion from high school. To satisfy these short-term outcomes, students are now required to perform at an acceptable level to avoid high stakes consequences.

Improving the mathematics achievement and problem-solving abilities of our students is important for 21st Century citizenship. The Office of Educational Research and Improvement (1997) stressed that mathematical literacy affects our nation’s economic productivity and global competitiveness. It is necessary to prepare students for success in a rapidly changing society where success depends on the ability to innovate quickly and continuously. Technology and business leaders agree that a key dilemma for the United States labor market is finding homegrown talent to fill jobs requiring high levels of education and technological skills (Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development, 2000). The consequences of continuing to produce a domestic labor market that is ill-
prepared to assume these more technically advanced professions are dire as companies can capitalize on a global market by taking their jobs to nations that are adequately prepared for these fields (Congressional Commission on the Advancement of Women, and Minorities in Science, Engineering and Technology Development, 2000). The Congressional Commission (2000) emphasizes the importance of taking deliberate steps to attract women, minority, and disabled students into SET professions because these groups supply two-thirds of our nation’s labor market and are grossly underrepresented in SET fields. These subgroups present a great opportunity to invest in our human capital and maintain our preeminence as a technologically advanced and innovative nation (Congressional Commission on the Advancement of Women and Minorities in Science, Engineering, and Technology Development, 2000). Schlechty (2009) emphasizes that critical thinking skills and the ability to work in collaborative teams are essential citizenship skills, and that memorization of facts is not sufficient for developing these essential skills. Developing the skills of “thinking, learning, and innovation” are essential to the success of workers in what Hargreaves (2003) terms the knowledge society. In its simplest form, the knowledge society is defined as a learning society characterized by professional collaboration and innovation to rapidly meet changing needs (Hargreaves, 2003). Hargreaves (2003) emphasizes that teaching students for success in the knowledge society should “promote deep cognitive learning” (Hargreaves, 2003). The National Council for Teachers of Mathematics (NCTM) have also identified
problem-solving as one of the essential processes in their *Principles and Standards* document (NCTM, 2006).

**Constructs Related to Problem-Solving**

**Struggles of U.S. Students with Problem-Solving Internationally**

Stevenson and Stigler (1992) contrast pedagogical practices between the typical U.S. teacher and teachers in Asian countries such as Japan and China. Key to this comparison were some of the misconceptions that Americans have about a rote instructional approach to instruction in the form of drill and kill exercises (Stevenson & Stigler, 1992). Teachers in the countries mentioned above were much more apt to pose challenging questions to students and provide them opportunities to reason through the problems (Stevenson & Stigler, 1992).

Math problem-solving is an area of concern around the mathematics achievement of U.S. students. It was found that U.S. students fell furthest behind on PISA tasks that required complex problem-solving (Darling-Hammond, 2010). Differences in approaches to math instruction consistently point to the observation that nations who significantly outperform the United States on math achievement have classrooms characterized by a focus on mathematical reasoning and problem-solving with students interacting with real-world problems (Darling-Hammond, 2010; Stevenson & Stigler, 1992). The emphasis is on fewer problems with more depth of understanding where collaborative work on one problem could very well take the whole class period (Darling-Hammond, 2010; Stevenson & Stigler, 1992).
The TIMSS study shed light on pedagogical differences between participating countries. Stigler and Hiebert (1999) focused specifically on such differences between 8th grade math teachers in Japan, Germany, and the United States. They constructed three distinct mottoes to characterize the norm of pedagogical practices in each country as follows. The motto for Japan’s general approach to math teaching was ‘structured problem-solving’ characterized by posing demanding problems with students taking an active role in inventing their own solution strategies (Stigler & Hiebert, 1999, p. 27). The motto attributed to Germany’s math instruction was ‘developing advanced procedures’ characterized by advanced procedural problems and technical precision with applying these procedures (Stigler & Hiebert, 1999, p. 27). Finally, the motto for United States mathematics instruction was classified as ‘learning terms and practicing procedures’ characterized by less advanced problems with less demands for mathematical reasoning (Stigler & Hiebert, 1999, p. 27). These mottoes are very telling and suggest some possible reasons for poor standings in international math performance comparisons of U.S. students. A host of other factors can also have an impact on our international standing, but the findings of the TIMSS acknowledges pedagogical practices in U.S. math instruction that de-emphasizes higher order math skills such as problem-solving.

These mottoes suggest that systematic attention to changing our pedagogy may be beneficial to mathematics learning of our students. Some process-product research has examined the relationship between various proxy variables of teacher behaviors and student achievement (Hill, Rowan, & Ball, 2005). These proxy
variables have included personal content knowledge of teachers, captured in our highly qualified tests under NCLB, years of teaching experience, number of seat hours of professional development, etc., and their resulting impact on student achievement (Hill et al., 2005). The results of such studies failed to show significant correlations between these proxy variables and student achievement (Hill et al., 2005). Hill et al. (2005) engaged in process-product research to examine the relationship between teachers’ mathematical pedagogy knowledge and student achievement. A key distinction when comparing this study to the relationship of personal content knowledge and student achievement is significant. The proxy variable of personal content knowledge describes a teachers’ ability to use math knowledge for their own purposes such as balancing a checkbook, budgeting, building new additions to a home, etc. Hill et al. (2005) examined “teachers’ content knowledge for teaching” which describes how teachers use their mathematical knowledge to make it comprehensible for their students. Key to this content knowledge for teaching is a teacher’s ability to deliver clear mathematical explanations, listen to students’ reasoning to guide their next instructional steps, build mathematical representations of problems, etc. (Hill et al., 2005). This study yielded a key finding that 1<sup>st</sup> and 3<sup>rd</sup> grade teachers who were instructed by teachers with strong content knowledge for teaching positively predicted their mathematics achievement (Hill et al., 2005). In other words, teachers with higher content knowledge for teaching produced higher results for 1<sup>st</sup> and 3<sup>rd</sup> grade math achievement in this study (Hill et al., 2005).
Intellectual Rigor and Challenge

The power that teacher expectations have on student performance is well documented. A study conducted by Robert Rosenthal and Lenore Jacobson (as cited in Sadker & Sadker, 1994, p. 253) revealed that ‘intellectual bloomers’ were identified by providing teachers with a phony list of students who were identified as ready to spurt ahead based on excelling test scores. This prophecy manifested outstanding scores among these students eight months later as every student on this phony list scored higher than they ever had before on this standard IQ test. The teachers’ belief that these students were ready to excel influenced their expectations of these students and their resulting performance outcomes (Sadker & Sadker, 1994, p. 253).

The illustration of this study has important implications for providing students with intellectually challenging work. Stigler and Hiebert’s (1999) report of TIMSS findings between Germany, Japan, and United States math pedagogy reveal that the average instruction in the United States is not nearly as academically challenging as that found in Germany and Japan. On average, it was found that U.S. eighth graders were studying content judged to be at the mid-seventh grade level when compared with Germany and Japan whose students were judged to be studying content at the high end of eighth grade to the beginning of ninth grade. This is consistent with the mottoes described above characterizing the instructional approaches of each country. Analysis of nearly 364 math lessons in U.S. classrooms were conducted in a study named Inside the Classroom where only 15% of the lessons were judged to be high in quality or
likely to enhance understanding of important math concepts (Weiss & Pasley, 2004). Furthermore, only one in five of these lessons were considered intellectually rigorous and containing effective questioning strategies (Weiss & Pasley, 2004).

As illustrated by the findings of the *Pygmalion in the Classroom* study, students respond to positive expectations for being successful with intellectually challenging curriculum (as cited in Sadker & Sadker, 1994, p. 253). Students relish the opportunity to perform successfully on challenging tasks. We can relate from our own personal accomplishments, the delight that accompanies achieving a challenging goal whether it be weight loss, setting a personal record in the weight room, repairing a car part that nobody else could figure out, etc. Students feel respected and become more engaged when their intellectual capacities are stretched. This was evident in a video sample of teaching captured in the classroom of a teacher in Japan, Mr. Yoshida. As part of his instructional routine, he engaged students in solving challenging math problems and having his students create variations of the problems for their peers to solve (Stigler & Hiebert, 1999, p. 40). During this instructional round, he commented to his students on how challenging they had created their problems to be and it was reported how excited students appeared as they solved one another’s challenging problems (Stigler & Hiebert, 1999, p. 40). While this is a snapshot of one classroom during one lesson, it is representative of what the average classroom in Japan looks like in terms of basing instruction on challenging math problems and
providing students the flexibility to solve such problems in multiple ways (Stigler & Hiebert, 1999, p. 40).

Multiple Solutions in Problem-Solving Approaches

The theory for this study is framed in Freire’s (1993) notion of problem-posing education whereby teachers and students learn mutually from one another through their dialogue on relevant problems. The motto for U.S. math instruction in TIMSS was classified as ‘learning terms and practicing procedures’ (Stigler & Hiebert, 1999). As a product of the U.S. education system, I can recount math instruction where we were required to memorize the process for solving an equation for a variable. In the equation $3x + 5 = 20$, for example, the following process would be followed to find the missing value for $x$:

1. Subtract 5 from both sides of the equation.
2. Rewrite the simplified equation as $3x = 15$.
3. Divide both sides of the equal sign by 3.
4. Cancel the 3’s on the left hand side of the equal sign to isolate $x$.
5. Write your answer as $x = 5$.
6. Substitute 5 in for $x$ to check that the left hand side of the equation does equal 20.

This process was then followed for many similar problems as in class or homework assignments. The recipe for solving for a variable was absent a meaningful context and left no room for multiple avenues to finding a solution. A problem-solving approach towards solving challenging math problems acknowledges and encourages multiple approaches for arriving at a solution.

Japan’s motto for math instruction was classified as ‘structured problem-solving’ (Stigler & Hiebert, 1999). In a typical lesson in a Japanese classroom, it
was common for students to present multiple solution strategies to a problem allowing for students to learn from one another. Furthermore, any errors in reasoning were not instantly corrected by the teacher, as is the case in typical U.S. math instruction. Mistakes in Japanese lessons were an essential part of the learning process (Stigler & Hiebert, 1999, p. 91). Our culture of avoiding errors in practice contradicts the very nature of learning. Trial and error, multiple revisions in thinking and work are an inherent part of human learning processes. Yet, our U.S. system of education is designed on an outdated factory model of assessing students to evaluate the final outcome of their understanding in the form of grades. (Stiggins, Arter, Chappuis, & Chappuis, 2006). It becomes more important to work for a grade rather than learning as a process. This contradicts the notion that human learning is a process of constantly becoming, and that we are incomplete beings who are perpetually learning (Freire, 1993). Modern proponents of formative assessment argue that the use of assessment rests with how results are used to improve student learning rather than evaluate their final product (Black, Harrison, Lee, Marshall, & William, 2003). Learning is never final and always evolving.

Models of problem-solving instruction exists in U.S. education as well, although not as a norm. Ball (1993) described dilemmas that she faced as a 3rd grade math teacher in making decisions about content, discourse, and community in her mathematics instruction. Decisions around content dealt with her decisions about how to best represent mathematics concepts such as negative numbers for 3rd graders. Should a building model be used with above ground floors
representing positive number and below ground floors representing negative numbers? Or, should money be used as the context with debt representing negative numbers? In making a choice on what model to use, do either of these models give an indication as to which numbers are greater in magnitude; -5 versus +2, for example? Is -5 not further away from 0 than is +2? (Ball, 1993).

Additionally, she also had to decide the style of discourse and role of community in her math classroom. She illustrated these difficult decisions with specific examples. For example, in her class some students made the argument that 6 is both an even and odd number because it can be divided into 3 groups of 2; 3 being an odd number of groups. She had to resist the temptation of correcting these students, framing herself as the lone expert, and instead facilitate this idea with further probing questions to encourage dialogue among students. Ensuing dialogue produced rich discussion among the students around number concepts (Ball, 1993). In such an environment, where answers were not as important as the discourse and social construction of meaning among the classroom community, this teacher-researcher was taking a risk, but nurturing habits of problem-solving more typical of the 21st Century workplace that they would be occupying.

The Carver Institute in San Antonio, Texas, spearheaded by former NBA All Star, David Robinson, provides another example of an educational system focused on inquiry and problem-solving in its approach (The Carver Academy, n.d.). In their curriculum overview, they describe the aims of their instructional programs as promoting inquiry and problem-solving through the presentation of
open ended problems and projects on which students invent solutions using advanced technology resources (The Carver Academy, n.d.).

While these education models provide examples of learning environments promoting inquiry and problem-solving, a vast amount of literature suggests that this is not the norm. It is important to have a systemic focus and collaboration to make schools resembling these models the norm in U.S. education (Congressional Committee on the Advancement of Women and Minorities in Science, Engineering, and Technology Development, 2000).

*Listening to Students’ Thinking as a Basis for Instruction*

An important process standard in the *Principles and Standards for School Mathematics* from NCTM (2000) is the idea of making connections between math content and student experience (as cited in NCTM, 2006). As noted in the above example on solving two-step equations, following steps to isolate a variable in order to know its value is divorced from any meaningful context or experience. Yet, math education in the U.S. is preoccupied with prescribing voluminous standards that teachers are expected to deliver within a seven month time frame before taking a high stakes state exam. The inherent nature of such a system communicates to teachers to teach lots of content quickly. Differentiating instruction based on feedback that students are giving during instruction or on assignments becomes less likely.

Our current accountability structure promotes mathematics curriculum that is “a mile wide, an inch deep” (Schmidt, 2004, p. 16). The typical U.S. math textbook covers 30 topics as compared to just 10 in Japanese textbooks (Schmidt,
Listening to students’ thinking to guide instruction can become increasingly difficult when as a teacher you are facing such a high volume of content that must be covered before high stakes testing. Such a system creates the conditions to view students as empty receptacles that must be filled perpetuating the teacher-student contradiction where the teacher has the knowledge and presumes the absolute ignorance of their students (Freire, 1993). Instruction that ignores the experience and voice of the students makes it unlikely that students will make meaningful connections in their learning. International comparisons in TIMSS have shown that this is a problem in U.S. math pedagogy. One construct analyzed in the study was how teachers from the various countries approach problems that were intended to assess students’ abilities to make connections using math. The data revealed that when teachers implemented making connections math problems, countries such as Japan and Hong Kong implemented these problems as intended. That is, they presented making connections problems as a problem-solving scenario that required them to make meaningful connections (Stigler & Hiebert, 2004, p. 15). They presented 48% and 46% of such problems, respectively, as legitimate problems requiring students to make connections (Stigler & Hiebert, 2004, p. 15). U.S. teachers in contrast did not require any of these problems to be implemented by making connections. They did, however, turn 59% of these problems into such a structure where they could use procedures to solve them (Stigler & Hiebert, 2004, p. 15).
Constructs Impacted by Higher Cognitive Questioning

The use of higher cognitive questioning in instruction has been shown to have positive impacts on a variety of learning constructs and across a variety of subject areas. Various cognitive questioning protocols have been shown to produce positive effects in student academic achievement, the development of students’ problem solving and critical thinking skills, students’ ability to regulate and monitor their own learning, and an increased sense of engagement and motivation in their work.

Higher Cognitive Questioning and Student Academic Achievement

Increases in student achievement are an important part of the educational landscape. Student achievement results determine a variety of educational decisions such as the identification of students to receive intervention support in their learning, the basis for awarding academic honors, the basis for applying performance labels to schools, etc. Given that such important decisions rely on student achievement outcomes, it is important to develop teaching strategies that contribute to its improvement.

Higher cognitive questioning is an educational strategy that has been shown to produce improved results in student academic achievement across a variety of subject areas and grade levels. Buggey (1971) found that the use of higher cognitive questions in 2nd grade social studies produced greater achievement gains than those classes characterized by lower cognitive questioning (as cited in Riley, 1979). Similar findings were reported in 6th grade social studies with achievement gains favoring students exposed to higher
cognitive questioning (Hunkins, 1968; as cited in Newton, 1978). Similar results were found in a study on the teaching of 3rd grade science. In this study, teachers received explicit training on the use of Bloom’s Taxonomy to design instruction characterized by higher level questioning. Students were assessed on a real-life task comparing the functioning of straws to roots in a plant system. Scoring was conducted using a 3-point rubric, a 0 indicating no proficiency of what was taught, and a 3 indicating advanced proficiency of what was taught. The students taught by the experimental group of teachers trained in higher cognitive questioning averaged a 1.8 on the rubric scale while students taught by the control group of teachers produced a 0.7 average (Caulfield-Sloan & Ruzicka, 2005). This indicates an entire standard deviation difference in achievement in favor of the student group exposed to higher cognitive questioning during instruction.

Problem-Solving and Critical Thinking Skills

The ability to problem-solve and think critically is highly regarded as an essential skill in the 21st century knowledge economy (Hargreaves, 2003). The use of higher cognitive questions is theorized to advance students’ cognitive abilities beyond the memorization of content (Gall, Ward, Berliner, Cahen, Winne, Elashoff, & Stanton, 1978). Higher cognitive questioning has been reported as a teaching strategy that promotes students’ abilities to perform proficiently on higher order and problem-solving tasks and to use higher order thinking to a greater degree in their responses (Caulfield-Sloan & Ruzicka, 2005; Kramarski & Gutman, 2006; Kramarski & Mizrachi, 2006). In middle school mathematics instruction, teachers that utilize various protocols built around higher
cognitive questioning have produced evidence of students being more effective at using higher order thinking in their responses and justification to mathematical tasks. A meta-cognitive teaching method referred to as IMPROVE has been the focus of various international studies whose implementation in the classroom has shown positive effects on higher order thinking in students (Kramarski & Gutman, 2006; Kramarski & Mizrachi, 2006). The IMPROVE meta-cognitive questioning strategy places emphasis on the following higher order skills: “(a) comprehending the problem, (b) constructing connections between previous and new knowledge, (c) use of appropriate strategies to solve the problem, and (d) reflecting on the processes and the solution” (Kramarski & Mizrachi, 2006). In the study conducted by Kramarski and Mizrachi (2006) forty-three 7th grade students in Israel were divided into an experimental and control group. Both groups received instruction via an online forum with a focus on solving real-life mathematical tasks. The experimental group received instruction that combined the forum discussion medium with the IMPROVE meta-cognitive questioning protocol to guide their problem-solving of real-life mathematical tasks. The control group received instruction through the online forum medium in the absence of the IMPROVE protocol. Findings from the study indicated that students who received the forum instruction combined with the IMPROVE meta-cognitive guidance more frequently used higher order arguments in problem-solving and justified their math reasoning with greater frequency than their counterparts in the control group (Kramarski & Mizrachi, 2006). The IMPROVE meta-cognitive questioning protocol showed similar success with sixty-five 9th
grade Israeli students (Kramarski & Gutman, 2006). In this study, students were also divided into an experimental and control group; one of which received the IMPROVE meta-cognitive questioning support in an E-Learning environment, while the students in the control group did not receive such meta-cognitive support in the same E-Learning environment. Results of the study indicated that students in the E-Learning environment who received the IMPROVE meta-cognitive guidance support significantly outperformed students who were not exposed to IMPROVE in problem-solving procedural and transfer tasks (Kramarski & Gutman, 2006).

This research literature suggests that systematic, higher order questioning during instruction can positively impact the higher order thinking skills of students such as problem-solving and critical thinking. These are skills that students must possess both for their academic success in formal schooling and for their long-term citizenship and professional success in a 21st century characterized by rapid innovation and change.

Self-Regulation of Learning

A major goal in education is to guide students to be independent learners who are self-reflective and looking to improve the quality of their thinking. In education, practices have been in place, that communicate to students that learning is something done to them. Students are accustomed to meeting deadlines set by their teacher for the sake of being assigned a grade. It is recognized that many teachers experience difficulty relinquishing control for learning to students, and that a need exists to employ practices allowing students
to take ownership of their thinking process rather than being passive recipients of learning (Caulfield-Sloan & Ruzicka, 2005).

There are many proponents of learning environments where teachers encourage students to take greater responsibility for their own learning and become more active in their learning process. The practice of comment-only marking is a strategy that has been shown to encourage students to take a more active role in their learning process (Black et al., 2003). Such feedback involves teachers only furnishing specific and meaningful comments to students on their work that they will in turn take action on when getting it back. This runs counter to the traditional practice of stamping a letter grade indicating completion, no further need for revision, and encourages students to compare their results to one another rather than acting on feedback to improve the quality of their learning (Black et al., 2003). This strategy is highlighted as an example of the importance of actively engaging students in their learning.

Higher cognitive questioning has been shown in various studies and literature to create greater self-monitoring of learning among students. Kramarski and Gutman (2006) found in their study that students in E-Learning environments exposed to meta-cognitive questioning support outperformed their counterparts in their ability to make use of self-monitoring strategies in problem-solving scenarios. A number of studies have also shown higher cognitive questioning to strengthen the executive function of the brain, which helps students become productive learners capable of taking responsibility for their own learning (Ediger, 1999; Penticoff, 2002; Smith, 2003; Vaidya, 1999; Williamson, 1996;
Self-regulated learning has been described as specific ways in which learners take control of their own learning (Kramarski & Mizrachi, 2006). It has also been a construct of focus in studies that investigated the impact of higher cognitive questioning. Students in an online forum math class supported by the IMPROVE meta-cognitive questioning strategy demonstrated a greater degree of self-regulated learning skills (Kramarski & Mizrachi, 2006).

Students want opportunities to take ownership of their learning. They come to our classrooms with interests and an inherent desire to learn. The types of questions posed during instruction are an expression of our expectations for students. Questions posed to elicit basic yes or no responses lead students to give the teacher a response that he or she wants. Posing questions of an open-ended nature that honors what students really think gives them opportunities to take greater responsibility for their learning. This is also a way to engage students in their learning, another important aspect promoted by higher cognitive questioning.

Engagement and Motivation

The learning of any skill is enhanced when we are engaged and motivated. We are motivated to succeed at tasks that are perceived as challenging and force us to stretch to attain the goal. This has been the driving force behind many innovations and accomplishments. Honoring this inherent need in our students is important to consider in designing our instructional practices. Traditional methods of delivering instruction often persist because of our fear to relinquish
control of learning as teachers over to our students. Organizational change theorists have also emphasized the point that schools need to recognize that they are in the business of student engagement, not compliance (Schlechty, 2009).

Higher cognitive questioning in instruction is supported as an approach that enhances student motivation and engagement in the learning process. Smith et al. (2007) stress the importance of teachers including affective questions as part of their instruction as a way to enhance student motivation. They describe these types of questions as those where a student’s interpretation is honored in discussions (Smith et al., 2007). It is further acknowledged that the combination of meta-cognitive and affective questions during instruction can enhance the critical thinking and motivation of students by virtue of giving them a voice (Vacca & Vacca, 1993; as cited in Smith et al., 2007). It is also suggested that students’ self-regulation skills are related to the degree to which they are meta-cognitively, motivationally, and behaviorally active participants in their own learning (PISA, 2003; Zimmerman, 1998; Zimmerman & Schunk, 2001; as cited in Kramarski & Gutman, 2006).

Arguments Against Quantifying Questioning

When Higher Cognitive Questioning Has Not Worked

Not all empirical efforts to measure achievement effects of higher cognitive questioning have produced positive results. Various studies have shown a negligible effect in comparing the achievement results of students in classrooms characterized by predominately higher cognitive questioning and those with lower cognitive questioning. The replication of a study conducted by Buggey (1971) in
a 2nd grade social studies class was carried out in a 5th grade classroom by Savage (1972) (as cited in Riley, 1979). This study did not reproduce the positive achievement effects seen for 2nd graders in classes characterized by higher cognitive questioning. Results showed an absence of a significant difference between students in a 5th grade classroom characterized by higher cognitive questioning when compared to a 5th grade classroom with lower cognitive questioning (Riley, 1979). Correlational studies of a similar nature were also conducted by Rosenshine (1971) and Durking and Biddle (1974) and also revealed no clear relationship between the frequency of use of higher cognitive questions and student achievement (as cited in Gall et al., 1978).

Philosophical Opposition to Attempts at Quantifying Questioning

Many studies have centered on analyzing the types of questioning taking place in the classroom and classifying such questions as higher level or lower level. Bloom’s Taxonomy (1956) has been used as a tool to help classify questions posed in classrooms according to his classification scheme. Findings and conclusions have been drawn as illustrated throughout this literature review regarding how the level of cognitive questioning impacts such constructs as student achievement on various assessments, higher order thinking skills such as problem-solving, and the degree to which these questions promote self-regulated learning in students.

There are opposing perspectives to the notion that instructional questioning can be classified, quantified, measured, and correlated with various constructs. One such line of thought is that questioning is a complex,
sociolinguistic process that must be viewed much more holistically than what is seen in studies attempting to capture correlational relationships around questioning (Roth, 1996). Roth’s (1996) research was a case study that attempted to capture the questioning strategies of a master teacher focusing on the complexity of issues to consider related to teacher questioning. He notes that questions should be evaluated on the basis of their *situational adequacy* considering such factors as the student’s learning style, ability, content complexity, gender of the student, setting of the community, etc. (Roth, 1996). This analysis of questioning from a more holistic perspective is indicative of the author’s philosophy that stands in stark contrast to attempts to establish relationships between cognitive questioning and student achievement, self-regulated learning, problem-solving skills, etc. The school of thought set forth by Roth (1996) is much more about acknowledging the complexity and dialogic nature in questioning of students. Viewing classroom questioning from an assumption that it can be quantitatively measured can be viewed as deemphasizing a teacher’s ability to make judgments about what will promote deep levels of student learning. The perspective offered by Roth implies a propensity of a field like education to think that all educational phenomena can be measured empirically. This is an important perspective to consider in reviewing this research, which is another effort to categorize questioning into higher and lower levels to measure its impacts on student achievement, and problem-solving skills. Roth’s perspective sheds an important light on the limitations inherent in
the approach taken in this research study but does not eliminate the validity that its conclusions can offer to classroom instruction and student learning.

*Why Cognitively Guided Instruction (CGI)?*

Teaching is a culturally embedded activity that has been hardwired into our schools from generation to generation (Stigler & Hiebert, 1999). From the perspective of education in the United States, this has perpetuated a teaching culture consistent with Freire’s (1993) notion of banking education particularly when it comes to math instruction. Our students are largely exposed to the instructional motto of ‘learning terms and practicing procedures’ (Stigler & Hiebert, 1999). In this review of the literature, we have seen the achievement implications on international comparisons that have manifested as a result of our predominant pedagogical style in math instruction. Preparing our students for competencies required in the 21st Century workplace will require changes to long-standing habits guided by a systematic approach to pedagogy that incorporates what is known to advance in depth learning of important math concepts.

Cognitively Guided Instruction (CGI) is one such framework for math instruction.

CGI emphasizes the importance of basing curriculum on problem-solving and communicating about problem-solving (Carpenter et al., 1999). Critical to this approach is giving students the opportunity to be actively involved in deciding how to solve a math scenario (Carpenter et al., 1999). Furthermore the curriculum in CGI is integrated, meaning that students practice computational skills in the context of thinking through word problems as opposed to learning skills first as a prerequisite to engaging with problem-solving scenarios.
(Carpenter et al., 1999). This is a dramatic shift from traditional practice that characterizes U.S. math classrooms.

The sequence of a typical CGI classroom would involve the following. The teacher would pose a problem to students allowing them to choose how they will solve it. Next, a variety of students will be expected to present their solutions to their peers. The teacher will engage in extensive questioning to ensure that the strategy is clear to everyone in the class. Students may then be asked to compare their strategies with one another (Carpenter et al., 1999, p. 96). This sequence is highly reflective of the constructs related to math problem-solving highlighted in this literature review. Students are instructed in a manner that requires them to demonstrate their understanding of math as they apply it to problem-solving scenarios.
Chapter 3

METHODS

Mixed Methods

The focus of this study is to investigate if the CGI model of primary math instruction, which is the independent variable in this study, affects three particular dependent variables. These dependent variables include the math achievement of 2nd through 4th grade students on quarterly benchmark assessments, the problem-solving abilities of 2nd through 4th grade students, and the level of questions posed by teachers during math instruction according to the Bloom’s Taxonomy classification scheme. This section describes the methods that were used to answer each of the following research questions:

• What impact does CGI have on math achievement results of 2nd through 4th grade students on quarterly benchmark assessments?

• What impact does CGI have on problem-solving abilities of 2nd through 4th grade students?

• What impact does CGI have on the level of questioning posed by teachers during math instruction in 2nd through 4th grade classrooms?

Participants and Sampling

The participants in this study were the 2nd through 4th grade students at Porfirio H. Gonzales Elementary School. These students were the focus of the first two research questions: (1) What impact does CGI have on math achievement results of 2nd through 4th grade students at Porfirio H. Gonzales Elementary School? and (2) What impact does CGI have on problem-solving
abilities of these 2nd through 4th grade students? This sample of students was
chosen because their math benchmark performance data is readily accessible to
me as the S.T.E.M. and Assessment Director of the Tolleson Elementary School
District. I also chose this sample of students because these 2nd through 4th grade
cohorts have baseline assessment data from the 2010 school year that served as
the basis of comparison for evaluating the effectiveness of this study’s innovation.
These same students were 1st through 3rd graders in the 2010-11 school year and
have taken the Galileo benchmark assessments, which served as baseline data.
Current year kindergartener’s will partake in the innovation but are not being
included in the documentation of this study because they do not take the Galileo
math benchmark assessments and did not have baseline data to serve as a point of
comparison in my analysis. Current year 4th graders are not being included in the
documentation of this study because they are 5th graders in the 2011-2012 school
year, and consequently, did not receive the CGI innovation.

Our nine 2nd through 4th grade teachers were included as study participants
specifically for the following research question: (3) What impact does CGI have
on the level of questioning posed by teachers during instruction? These teachers
were selected for many of the same reasons that we chose our student participants.
The teachers all administer the Galileo benchmark assessments on a quarterly
basis. Their scores are also easily accessible to me as the Director of S.T.E.M.
and Assessment Programs for our district.

This study began with 9 teacher participants. A total of 7 teachers
participated in the study from the beginning to the end. Of the 7 teachers, 3 were
2nd grade teachers, 1 taught a multi-age classroom of 3rd through 5th graders, 1 was a 3rd grade teacher and 2 were 4th grade teachers. Table 3 provides further demographic information regarding the teacher participants.

Table 3

Teacher Characteristic Information

<table>
<thead>
<tr>
<th>Teacher Pseudonym</th>
<th>Yrs. Of Teaching Experience</th>
<th>Primary Teaching Assignments in Career</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher 2A</td>
<td>4</td>
<td>K-2</td>
</tr>
<tr>
<td>Teacher 2B</td>
<td>3</td>
<td>K-2 and 3-5</td>
</tr>
<tr>
<td>Teacher 2C</td>
<td>23</td>
<td>K-2 and 3-5</td>
</tr>
<tr>
<td>Teacher 3B</td>
<td>7</td>
<td>3-5</td>
</tr>
<tr>
<td>Teacher 3C</td>
<td>14</td>
<td>3-5</td>
</tr>
<tr>
<td>Teacher 4A</td>
<td>18</td>
<td>3-5</td>
</tr>
<tr>
<td>Teacher 4C</td>
<td>9</td>
<td>K-2 and 3-5</td>
</tr>
<tr>
<td>Total</td>
<td>78</td>
<td></td>
</tr>
</tbody>
</table>

Note: K-2 indicates teaching assignments between kindergarten and 2nd grade; 3-5 indicates teaching assignments between 3rd and 5th grades.

The Innovation

I have chosen CGI as the innovation for this study because it uses problem-solving scenarios as the basis for curriculum. This is important because, as shown in the literature review, high achieving nations in math have the commonality of using challenging math as the basis for instruction (Stigler & Hiebert, 1999). Furthermore, the call to develop 21st Century Learners who are adept problem-solvers call for frequent and ongoing opportunities to engage in problem-solving in contexts with a deeper level of rigor that our textbook-driven system has produced for decades.
CGI’s Structure

CGI utilizes problem-solving scenarios to address the skills of addition, subtraction, multiplication, division, comparison and part-part-whole in context as opposed to being taught as isolated skills (Carpenter et al., 1999). Each of these basic math operations is further sub-categorized into specific problem types.

Addition problems, for example, are referred to as “Join” problems. Join problems are further categorized as “Result Unknown,” “Change Unknown,” and “Start Unknown” problem types (Carpenter et al., 1999). An example of a Join Result Unknown problem may be as follows:

Connie had 5 marbles. Juan gave her 8 more marbles. How many marbles does Connie have altogether?

Another problem type characterizing subtraction are “Separate” problems which are further categorized into “Result Unknown,” “Change Unknown,” and “Start Unknown” paralleling the classification for Join problems. A similar subdivision into problem types occurs for multiplication and division problems. Table 4 illustrates the various problem types that comprise the CGI framework.

Table 4

<table>
<thead>
<tr>
<th>Problem Types</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Join Result Unknown</td>
<td>Kenny had 9 ducks. Joe gave him 6 more ducks. How many ducks does Kenny have altogether?</td>
</tr>
<tr>
<td>Join Change Unknown</td>
<td>Julie baked 19 cookies. Her mother brought over some more cookies for the party. They took 31 cookies to the party. How many cookies did Julie’s mother bring for the party?</td>
</tr>
<tr>
<td>Join Start Unknown</td>
<td>Claudia has the most points scored this season on her basketball team. She scored 24 points in her last game. For the season, she has 362 points. How</td>
</tr>
</tbody>
</table>
many points did she have before her last game?

Separate Result Unknown
Laura had 23 stuffed animals at home. She gave 8 away to her younger cousin to make room for new toys. How many stuffed animals does she have left?

Separate Change Unknown
Danny decided to give away some coins from his coin collection. He had 53 coins in his collection. He gave some to his friend Tim. After giving Tim the coins, he had 39 coins remaining. How many coins did he give Tim?

Separate Start Unknown
Tina is a WNBA fan. She has had many of the players sign autographs for her. At the Phoenix Mercury game on Friday, she got 7 more players to sign their autograph. She now has autographs from 33 WNBA players. How many autographs did she have before the game on Friday?

Multiplication
Lesley took out 4 bags to put some pieces of Halloween candy. She put 8 pieces of Halloween candy in each bag. How many total pieces of Halloween candy did she have?

Measurement Division
The librarian is going to display 35 books on 7 shelves. If she places an equal number of books on each shelf, how many books will be displayed on each shelf?

Partitive Division
The librarian wants to display 35 books. She plans to place 5 books on each shelf. How many shelves does she need to show all her books?


The CGI Progression

CGI is designed to help students develop math fact fluency in the context of problem-solving scenarios. In the CGI model, strategies progress from “direct modeling,” to “counting strategies,” to “derived number facts” as the basis for students solving problems (Carpenter et al., 1999). Each successive progression represents increased levels of sophistication and efficiency in dealing with numbers. Direct modeling involves students creating physical representations of a problem in order to solve it (Carpenter et al., 1999). For example, in the
problem above, a student might sort out 5 blue unifix cubes to represent the marbles that Connie has. The student may then use 8 yellow unifix cubes to represent the marbles that Juan gave to Connie. He or she may then combine these cubes and count their total to get the solution. *Counting strategies* is more typically represented by students using their fingers to count on from an initial number (Carpenter et al., 1999). For example, a student may have Connie’s 5 marbles in their head as the place to start counting from. From there, they may start lifting a finger to represent the sixth marble, then the seventh, until they reach 13 and state their solution. Finally, *derived number facts* involves a student using their number sense absent any manipulative assistance to arrive at a solution (Carpenter et al., 1999). For example, in the problem being illustrated, the student may say that he or she knows that 5 plus 5 is 10, and they still need 3 more to account for Juan’s 8 marbles resulting in a solution of 13 altogether.

*The CGI Professional Development Timeline*

The implementation of the CGI professional development innovation began in August of 2011. The timeline for implementation unfolded as indicated in Table 5.

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Overview of CGI principles. 2. Introduction to the Addition</td>
<td>1. Overview of CGI principles. 2. Introduction to the Addition and</td>
<td>1. Analysis of student work samples that teachers brought from classrooms.</td>
<td>1. Analysis of student work samples from classrooms using K-2 AZ Counts</td>
<td>1. Teacher discussion on what has worked and concerns around implementation.</td>
<td>1. Teacher discussion on what has worked and concerns around implementation.</td>
</tr>
</tbody>
</table>

Table 5

CGI Implementation Timeline
| Addition and Subtraction Problem Types. | Subtraction Problem Types. | 2. Matched CGI solution strategies with student work samples and number sentences with problem types. | 2. Teachers worked on story problems and shared to see multiple solution strategies. | 2. Matched CGI strategies with student work samples and number sentences with problem types. | 2. Analyzed examples of student work on multiplication story problems using guiding questions. | 3. Examination of student work samples on CGI Addition and Subtraction Problem types. | 3. Looked at multiplication problems and assigned these for next session. | 3. Analyzed examples of student work using AZ Counts questions. | 3. Introduced Division Problem Types and typical student strategies. |
|---------------------------------------|---------------------------|-------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|-----------------------------------------------|-----------------------------------------------|-------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|----------------------------------------------------------------|
| 3. Examination of Student Work Samples on CGI Addition and Subtraction Problem Types. | 3. Examination of student work samples on CGI Addition and Subtraction Problem types. | 3. Used questions from K-2 AZ Counts Training as basis for analyzing work. | 4. Matched CGI strategies with student work samples and number sentences with problem types. | 3. Looked at multiplication problems and assigned these for next session. | 4. Looked at multiplication problems and assigned these for next session. | 4. Looked at multiplication problems and assigned these for next session. | 4. Introduced Division Types and Strategies. | 4. Introduced Division Types and Strategies. | 4. Analyzed examples of student work on multiplication story problems using guiding questions. | 4. Analyzed examples of student work on multiplication story problems using guiding questions. |

The plan for implementation of CGI is based on an ongoing model of support. A traditional workshop format of professional development can minimize the effectiveness of the CGI model in 2nd through 4th grade math instruction. Our district made the decision to initially provide our kindergarten and 1st grade teachers with training using the CGI framework for math instruction. This initial decision was based on the fact that we were introducing the Common Core Standards with our kindergarten and 1st grade students this year. The introduction of our S.T.E.M. initiative and our collective awareness of the need to provide support to teachers and students in the area of math prompted a decision to expand CGI training to all kindergarten through 4th grade teachers in our district.

The next step in our process of organizing training for our K-4 teachers was to outline the format and structure of the professional development. Through work in common core workshops in the 2010-2011 school year, we were
fortunate to learn of an external trainer who came with 20 plus years of teaching experience and certified training with the CGI framework. Based on her strong reputation and experience as an effective math teacher and certified CGI trainer, we secured the services of our consultant to provide professional development to our kindergarten through 4th grade teachers. We discussed an initial plan to provide 3 professional development sessions to our teachers over the course of the Fall 2011 semester. In dialogue with our consultant, we agreed that the professional development should be as customized as possible to meet the needs of all of our teachers. It was agreed that the training would be limited to no more than 30 participants at a time as a means to ensure better quality of training and addressing teachers’ needs. To accomplish this goal, a total of 6 training sessions were scheduled as outlined in the timeline in Table 2 above. The trainings were held on 6 Wednesdays throughout the Fall 2011 session as this day is designated for the school district to provide professional development to teachers. They were conducted from 3:30 to 5:30pm to ensure that teachers from all four campuses could attend. Two of the 4 schools dismiss students at 3:15pm.

The 6 training sessions were conducted to include a mix of CGI theory with actual practice at the classroom level. In the first session of trainings, our consultant spent time explaining the major philosophical foundations behind CGI. Central to this message was that students come into the classroom with intuitive understandings about math even before their formal schooling. For example, most children have had the experience of being asked to share something with siblings or friends in a way that is fair to all. I can recall my own initial learning
of equality when my neighbor tried to insist on having the larger piece of a Big Hunk bar that my grandmother had purchased for me. I did not know what a numerator or denominator was at 4 years of age, but I did know that my friend was not making away with the larger portion of my candy bar. Our consultant also stressed how teaching with CGI honors this intuitive understanding that students bring to the classroom by giving them the opportunity to grapple with problems in context prior to teaching them the steps in advance. Children enjoy being presented with riddles and trying to solve them. CGI plays to the inherent curiosity and exploratory nature that children possess and establishes a more favorable disposition towards mathematics among students who experience this subject in this manner. It was emphasized that instruction should begin with posing problems to students and letting them grapple with the problem. The teacher would become the facilitator of student learning rather than the purveyor of information. Establishing this foundation was a major focus of the first round of trainings.

In addition to establishing the philosophical foundations behind CGI, our trainer also introduced the different Join and Separate problem types. She showed teachers videos of students’ approaches to solving these types of problems. Discussion followed the viewing of how students solved these problems on video. Teachers also viewed samples of student work in relation to the strategies that they used to solve the different types of problems. Teachers left the first training with the assignment of posing a Join or Separate problem to
return with for the second training as a foundation for further analysis of work samples.

In the second round of trainings, the trainer made the link between the various problem types in the CGI framework and how they are manifested as number sentences. For example, a *join change unknown* was presented similar to the one shown below.

*Laura had 15 color pencils in her art supplies box. For her birthday, her father bought her some more color pencils. She placed her new color pencils in her box and had a total of 39. How many color pencils did her father buy for her?*

Teachers then practiced writing a number sentence for the above situation in the following format:

\[ 15 + p = 39 \]

Teachers had multiple opportunities to practice matching various algebraic number sentences to the different problem types. This was to demonstrate the link to pre-algebra concepts in upper grades.

The latter portion of the second round of trainings involved teachers analyzing the student work samples that they posed to their students as their homework from the first training. Teachers worked in small groups rotating between five pieces of butcher paper containing the student work, which had been posted on them. Teachers discussed what math concepts students seemed to understand as well as what their common misconceptions were. They also discussed what problem-type each problem represented and whether students used
direct modeling, counting up or derived number facts strategies to solve. It was also communicated at this training that teachers should be minimally implementing CGI-style instruction in the classroom once per week. Teachers were introduced to multiplication problem-types and asked to present a multiplication problem to students as their next set of homework prior to the third and final round of trainings.

The final trainings were focused on discussing implementation of CGI in the classroom. Teachers shared what was working as well as what some common challenges were. Due to some confusion in scheduling, the K-2 training was delivered by our district S.T.E.M. Coach and I. Our consultant delivered the final training to our 3rd and 4th grade teachers. In addition to discussion around implementation, analysis was conducted on student work samples more specifically to the multiplication problems that teachers presented to their students. The analysis was facilitated using guiding questions that were learned from a K-2 AZ COUNTS training in which our consultant had been involved as well as our district S.T.E.M. Coach, kindergarten and 1st grade teachers and myself. The questions that guided the discussion were as follows:

- What strategy did the student use to solve the problem?
- Do you see evidence of student understanding?
- Did the student get the correct answer?
- What else do you notice on this paper?

Lastly, the teachers were introduced to the various division problem types and sample problems that could be used with students in the classroom. In the final K-2 training, teachers also engaged in an activity of working on a set of problems.
in small groups of 3 to 4. A representative from various groups were then called up to present how they solved the problems. The purpose of this activity was for teachers to see the value in seeing problems solved in multiple ways as the CGI framework asks them to do with students.

*Data Collection*

Innovation diffusion has eliminated the possibility of conducting a quasi-experimental design. It is not possible to use a control group as the CGI innovation for teaching math was used across all schools in our district. Instead, student performance data on math benchmark assessments from the 2010-2011 school year were used as baseline data on which to make comparisons.

What impact does CGI have on the mathematics achievement of 2\textsuperscript{nd} through 4\textsuperscript{th} grade students at P.H. Gonzales Elementary School?

*Quantitative Data*

*Archival Time Series to Compare Trends*

I used an archival time series design to examine the trends in math achievement prior to the implementation of the CGI instructional method and following the use of the model after a one-semester period in the Fall of the 2011-2012 school year (Amrein & Berliner, 2002). In carrying out this design, I examined the trend of the 2010-2011 1\textsuperscript{st}, 2\textsuperscript{nd}, and 3\textsuperscript{rd} grade students on their four quarterly Galileo math benchmark assessments taken in October, December, March and May of 2010-11 respectively. The mean scores and corresponding standard deviations of our 1\textsuperscript{st}, 2\textsuperscript{nd}, and 3\textsuperscript{rd} grade cohorts were computed using SPSS descriptives. Prior to computing the means, data were imputed using SPSS descriptives.

58
to improve the validity of the population statistics being derived from the data sets. This process was conducted in two phases. In the first phase, data was imputed by replacing missing values in each of 4 data sets; the Fall math benchmarks of 2010, the Winter math benchmarks of 2010, the Spring math benchmarks of 2011 and the year end math benchmarks for 2011. This was done for the entire population of 2nd, 3rd and 4th grade students in our district. There were a total of 3 separate populations for which this process was done; the 2nd grade population of students, 3rd grade population of students and 4th grade population of students across the Tolleson Elementary School District.

The scores used to communicate student performance on quarterly benchmark assessments are developmental level scores. A developmental level score is different from traditional raw scores. Traditional raw scores are those such as 75%, 62%, 88%, etc. We readily interpret a score such as 88% as a student performing at a B+ level. The shortcoming of a raw score is that it assumes that every item on the assessment was equal in terms of its difficulty. The developmental score negates this faulty assumption by ascribing greater weight to more difficult problems on an assessment, which is a central feature of Item Response Theory (Harris, 2011). A challenge of the developmental level scale on Galileo is that it changes from grade level to grade level and even from one test to the next in the same grade level. It is for this reason that the mean developmental level scores for each 2nd, 3rd and 4th grade student from P.H. Gonzales Elementary School was standardized.
Standardizing values is the process of converting values in a data set from their original units into standard deviation units from a population mean. When a score is standardized, it is now on an equal scale; the number of standard deviations away from the mean making forecasting through linear regression possible for the archival time series.

The scores of P.H. Gonzales 2nd, 3rd and 4th graders in the 2010-11 school year were standardized one grade level and one testing period at a time. For example, the scores for all 2010 2nd graders were standardized first for the Fall 2010 math benchmark assessment. SPSS was then used to compute the mean standardized score and standard deviation. This mean standardized score then became the first point on the archival time series for the current year 3rd graders, who were 2nd graders last year. This process was repeated for the Winter 2010 math benchmark assessment as well. A standardized mean score was obtained for all 4 quarterly benchmark assessments for P.H. Gonzales Elementary 2nd, 3rd and 4th grade students. At the end of this process, each participating grade level had 4 points on their archival time series, which formed the foundation for conducting linear regression, which will be discussed soon.

The next step in constructing the archival time series for this study was to use the 4 data points of standardized mean scores for each participating grade level to infer what the expected achievement for these 3 cohorts would be on their Fall 2011 and Winter 2011 math benchmark assessments. This was done using SPSS’ regression application. To accomplish this, the assessment number in our series of 6 assessments served as the independent variable, and the standardized
mean scores served as the dependent variable. This process produced 3 regression equations; one for each participating grade level. These equations are indicated below and were used to forecast a score for the Fall and Winter 2011 math benchmark assessments respectively:

- 2nd Grade: \( Y = -0.619 + 0.062 \times X \)
- 3rd Grade: \( Y = -0.468 + (-0.091) \times X \)
- 4th Grade: \( Y = -0.317 + (-0.088) \times X \)

The next step in archival time series was to compute standardized mean scores and standard deviations for each grade level cohort for their Fall 2011 and Winter 2011 math benchmark assessments. These statistics provided the actual values for the 5th and 6th points in the archival time series. These actual values were compared with the expected values derived from linear regression. Finally, six t-tests were conducted to determine if the differences between the expected and actual values on the Fall and Winter 2011 math benchmarks were statistically significant. These were conducted for each grade level.

Comparing Dissimilar Group Growth

A supporting method to answer this research question and triangulate my data was to collect math performance data for our 2nd through 4th grade students in the 2011-2012 school year on Fall and Winter math benchmark assessments. The standardized mean scores from the archival time series were used to compare the growth of different cohorts. This was accomplished by comparing the growth of the 2010 2nd graders with 2011 2nd graders, 2010 3rd graders with 2011 3rd graders and 2010 4th graders with 2011 4th graders. This was accomplished by determining if the Fall to Winter growth for each of these cohorts were considered
significant. This was accomplished by running t-tests for dependent samples on each of the 6 cohorts just described.

A *nonequivalence* threat to validity existed in this method because the progress of three cohorts of students was being evaluated in this study (Smith & Glass, 1987). It was entirely possible that one of these cohorts might just be collectively statistically higher math achievers than other cohorts in this study. To minimize this *nonequivalence* threat, three t-tests were conducted on our participating cohorts of 2<sup>nd</sup>, 3<sup>rd</sup> and 4<sup>th</sup> graders from P.H. Gonzales Elementary School. The purpose of these t-tests was to determine if any or all of these cohorts demonstrated statistically significant growth or loss on their math achievement from their Fall 2010 to Winter 2010 math benchmark assessments. Furthermore, did any groups significantly outgain or decline in comparison to other participating cohorts?

*Instrumentation* threats also need to be accounted for in this method (Smith & Glass, 1987). Archival time series data can show trends in performance over an extended period of time for the 2011-2012 2<sup>nd</sup> through 4<sup>th</sup> graders, however, they are taking a different assessment consisting of differential performance objectives at each quarterly benchmark point in time. To help control for instrumentation threats, the comparison of the dissimilar groups is being conducted. The assessments created for the 1<sup>st</sup> and 2<sup>nd</sup> quarter benchmarks of the Fall semester of 2011 was conducted using the same pacing guides as last year as well.
What impact does CGI have on problem-solving abilities of students?

To answer this question, a mixed methods approach was used. Evaluating the problem-solving abilities will require going beyond their math achievement results on the benchmark tests which primarily requires students to bubble in answers for efficiency of grading on scantron sheets. Therefore, to get a more in-depth view of how the math problem-solving skills of students are impacted by receiving instruction based on CGI, a sample of student work was evaluated at the beginning of the study and at the end of the study to see how their problem-solving skills evolved over the duration of the CGI intervention. These two data points were chosen to evaluate how their problem-solving skills evolved over the course of the intervention. Students were provided authentic problem-solving tasks on which to go through the process of problem-solving. Teachers selected the problem or problems to pose to the students to be reflective of current skills that they were focusing on in their instruction. A rubric was used to evaluate their problem-solving skills on this task. The purpose of the rubric was to be able to quantify their problem-solving skills and obtain a measure of how this skill is progressing over the course of the semester.

Quantitative Data

Student Work Samples

A total of 47 work samples were chosen to evaluate using the rubric in Appendix B. Initially, the plan was to randomly select a stratified random sample of 5 students from each of the 9 classrooms involved in the study to evaluate a pre and a post work sample. Permission forms for these 45 students would then be
sent home to gain parental permission to evaluate the student work samples. It was difficult to predict the kind of return rate of the permission slips. Instead, permission slips were sent home with all students in 2nd through 4th grade at P.H. Gonzales Elementary School. A total of 94 permission forms were returned. In order to select a student work sample for evaluation, two criteria had to be met. First, each student had to have turned in an initial permission from signed by their parent giving consent for their participation in the study. Secondly, of those students who submitted an initial permission slip, they had to have completed a pre-work sample, which was administered in August or September of 2011 at the outset of the study and have a post work sample to serve as a matched pair. A total of 47 students met these criteria and had the matched pairs of pre and post work that were evaluated using the rubric in Appendix B. Twenty-eight of these work samples were from 2nd grade students; 11 were from 3rd grade students, and 8 were from 4th grade students. The work samples were evaluated to ascertain the changes in how students approached problem-solving work from the beginning to the end of the Fall 2011 semester.

The process used to evaluate the work samples began by validating the problem-solving rubric that was used for this purpose. The researcher in this study and two members of the curriculum and instruction team in his district evaluated 3 work samples for a total of 6 story problems using the problem-solving rubric. Feedback was offered by the team, which was applied to making revisions in the rubric. Inter-rater reliability was accurate on problems that were evaluated. A table was created for each teacher to capture changes, pre to post,
on how students scored on the four different elements of the rubric. Additionally, the problem types that teachers posed pre to post were noted because they range in their degree of rigor and challenge. The rubric consisted of 4 elements; extent of work shown, presence of mathematical representations, persistence (in problem-solving), and depth of reasoning. Descriptors associated with each element are presented in Appendix B.

Qualitative Data

Classroom Videotaping

At the outset of the study, 9 teachers agreed to participate in this research study. The teachers were provided with a permission form seeking their approval to participate in the study. They were informed that their participation was voluntary and of their option to remove themselves at any time that they chose. Videotaping of short segments of instruction was conducted at three different points in the Fall 2011 semester. The rationale for three data points was to capture a longitudinal picture of how students’ approaches to problem-solving developed during their exposure to CGI-style instruction and how teachers’ practices in terms of questioning students evolved over this same duration. The video tapings helped to answer the following two research questions:

1. What impact does CGI have on students’ problem-solving abilities?
2. What impact does CGI have on the level of questioning posed by teachers during instruction?

Of the seven teachers who participated in the study from beginning to end, a total of 21 classroom video-tapings were conducted. The mean duration of the
recordings was 15 minutes 48 seconds with the shortest duration being 9 minutes 11 seconds and the longest being 31 minutes 41 seconds. The reason for this discrepancy was that in some observations, it took the teacher a little longer into the lesson to get to a problem-solving scenario. The total duration of video recordings was 5 hours 32 minutes 47 seconds. Table 6 provides a comprehensive inventory of the details of video recording data for this study.

Table 6

Inventory of Video Recordings (Time in minutes and seconds)

<table>
<thead>
<tr>
<th>Teacher</th>
<th>1st Recording</th>
<th>2nd Recording</th>
<th>3rd Recording</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher 2A</td>
<td>17:41</td>
<td>14:00</td>
<td>14:44</td>
</tr>
<tr>
<td>Teacher 2C</td>
<td>14:08</td>
<td>11:17</td>
<td>26:45</td>
</tr>
<tr>
<td>Teacher 3B</td>
<td>12:12</td>
<td>15:09</td>
<td>18:24</td>
</tr>
<tr>
<td>Teacher 3C</td>
<td>12:56</td>
<td>16:49</td>
<td>16:01</td>
</tr>
<tr>
<td>Teacher 4A</td>
<td>9:11</td>
<td>14:06</td>
<td>11:32</td>
</tr>
<tr>
<td>Teacher 4C</td>
<td>13:12</td>
<td>31:41</td>
<td>23:52</td>
</tr>
<tr>
<td>Totals</td>
<td>1hr. 31 min.</td>
<td>1 hr. 57 min. 53 sec.</td>
<td>2 hrs. 4 min. 32 sec.</td>
</tr>
</tbody>
</table>

Code Development

The analysis of data in the video recording led to the development of 31 codes. The ideas attained from the principles of student-centered and teacher-centered instruction in Cuban’s (1993) work and its relationship to the student-centered philosophical underpinnings of the CGI framework influenced the codes that were developed from viewing the video recording. Open coding was employed to categorize the types of student and teacher behavior that took place during problem-solving instruction. These codes are presented in Appendix C of this study and formed the basis for assertions made in this section of the study.
Axial coding was then employed to develop a total of 4 overarching themes that included \textit{student-centered pedagogy}, \textit{student behaviors}, \textit{teacher-centered pedagogy} and \textit{CGI implementation levels}. These themes are briefly described to clarify their meaning.

\textit{Student-centered pedagogy} (Cuban, 1993) referred to the practices that teachers employed in their instruction that were consistent with the philosophical underpinnings of CGI instruction which is heavily rooted in student problem-solving. Some of the codes under this theme included posing problem-solving opportunities to students, encouraging multiple ways to solve a given problem and providing students the opportunity to share these strategies with their peers.

\textit{Student behaviors} as a theme referred to the learning behaviors in which students engaged during problem-solving based math instruction. This included the type of strategies that students used in solving a problem as defined by the CGI framework such as using \textit{direct modeling strategies}, \textit{counting strategies} or \textit{derived number facts strategies} to solve a problem. Additionally, behaviors such as students collaborating with one another in problem-solving, demonstrating flawed reasoning in understanding a problem and engaging in argumentation were among the behaviors included and coded under this overarching theme.

\textit{Teacher-centered pedagogy} (Cuban, 1993) referred to those instructional practices that stood in contrast to \textit{student-centered pedagogy}. Teacher behaviors such as prescribing the solution strategy for students to use were captured under this theme as a code. Additionally, posing questions requiring minimal cognition
was included under this theme as well as the teacher providing guidance to such a
degree that they were doing the thinking for the students.

*CGI implementation levels* was a theme that encompassed the degree to
which teachers were instituting a student-centered pedagogical style of instruction
that was consistent with the principles and philosophy of CGI in their routine
practice. Noted in this section was the frequency with which teachers provided
problem-solving opportunities as opposed to traditional algorithmic, rote-style
problems. Also in this section, obstacles hindering the implementation of the CGI
framework in math instruction were noted such as difficulties with classroom
management or infrequent checking for student understanding of the questions
being posed to students.

The process of analyzing classroom videotapes involved using the codes
that were developed as a framework when viewing. Copious notes were taken
much like scripting when observing a lesson. After viewing the video and taking
notes, they were analyzed using the codes from the codebook in Appendix C. On
the notes, lines from the script were highlighted in yellow if the teacher practice
or student behavior was reflective of student-centered instruction propounded by
the CGI framework. They were highlighted in orange if the teacher practice or
student behavior was more reflective of a teacher-centered instructional style.
Additionally, tally marks were placed next to each code to indicate the frequency
with which a given behavior or action reflected one of the codes. This was done
for each teacher in each round. The resulting tally charts by code were then
condensed into one large chart to view trends across rounds in terms of how behaviors related to different codes changed over the duration of the study.

*Teacher Interviews*

A total of 7 interviews were conducted with teachers who began and ended in the study. The interviews were conducted at the conclusion of this research study during the early part of December 2011. A total of 8 questions were posed to participating teachers. The questions are presented in Appendix D of this study. The purpose of the interviews was to get teachers’ impressions around several constructs related to the training and implementation of CGI. It was emphasized to teachers that the researcher was coming in a non-evaluative role to encourage candid responses to the questions posed. These constructs included what teachers’ impressions were of the training. Other questions aimed at gauging to what degree teachers implemented the CGI framework into their instruction. Questions were also posed to ascertain the philosophical alignment that teachers had with the CGI approach to math instruction. Finally, questions were included to see if teachers noticed changes in student work on problem-solving scenarios and if my role as a researcher in any way influence their impressions of the CGI training or its implementation.

Table 7 delineates an inventory of the specifics on the teacher interviews.
Table 7

Teacher Interview Inventory

<table>
<thead>
<tr>
<th>Teacher Name</th>
<th>Interview Duration (min: sec)</th>
<th># of Transcribed Words</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher 2A</td>
<td>7:54</td>
<td>1,191</td>
</tr>
<tr>
<td>Teacher 2B</td>
<td>9:04</td>
<td>1,594</td>
</tr>
<tr>
<td>Teacher 2C</td>
<td>6:30</td>
<td>847</td>
</tr>
<tr>
<td>Teacher 3B</td>
<td>8:54</td>
<td>1,249</td>
</tr>
<tr>
<td>Teacher 3C</td>
<td>9:10</td>
<td>1,130</td>
</tr>
<tr>
<td>Teacher 4A</td>
<td>7:12</td>
<td>998</td>
</tr>
<tr>
<td>Teacher 4C</td>
<td>10:36</td>
<td>1,645</td>
</tr>
<tr>
<td>Totals</td>
<td>59:20</td>
<td>8,654</td>
</tr>
</tbody>
</table>

Codes were developed from interview transcriptions in a manner similar to the process carried out in developing videotaping codes. Responses of all 7 teachers were read through in their entirety. The researcher returned to the transcripts reading responses to each question one by one. Open coding was used to establish initial codes based on teachers’ responses to questions. Axial coding was aligned to the topic of the question being posed. For example, the first question asked was about teacher impressions of the training. From this, the axial code of TCHRIMP was developed. The codebook for the interview transcriptions is presented in Appendix E.

What impact does CGI have on the level of questioning posed by teachers during instruction?

A classification matrix was used containing the six levels of Bloom’s Taxonomy to categorize the frequency of questions at each of the levels that teachers are posing during instruction. This classification matrix is presented in Appendix A and was adapted from the work of Caulfield-Sloan and Ruzicka (2005). As emphasized in this study’s literature review, the dependent variable of
the level of questions that teachers pose in instruction is important because of its link to promoting better problem-solving among students. This was done at the beginning of the study and near the end of the study. The purpose of using this pre- and post-format is to see how questioning techniques from teachers evolve over the duration of the study as a result of using the CGI model for math instruction. Higher-level questions were classified as those questions at the application level and higher according to Bloom’s Taxonomy. Application is chosen as the lowest level due to requiring more than literal recitation or translation that is characteristic of the knowledge and comprehension levels of Bloom’s (Bloom, 1956).

**Qualitative Data**

Classroom videotaping was a source of data collected to answer the question of how CGI affects the level of questioning that takes place in classroom instruction. For this purpose, the same videotapes collected to analyze the evolution of student approaches to problem-solving scenarios were also used to gauge the evolution of teacher questioning over the duration of this study. A total of 7 video tapings were included to capture the instructional segments of teachers who began with and finished the study. The inventory of the video tapings is included as part of Table 3 above. To get a thicker description of the nature of interaction between the student and teachers alongside the questions being posed, videotaping provided a more descriptive account of how the questions impacted the learning environment. I used an interpretive fieldwork approach to describe the evolution of teachers’ questioning techniques over the duration of this
innovation (Erickson, 1986). Erickson (1986) describes the “invisibility of everyday life” that involves the details and nuances of what occurs in a local context and that can only be understood by in depth analysis of the context. Posing of higher-level questions without attention to these deeper details and interpretation of their meaning fails to capture how questioning is impacting the learning environment. Using these transcripts, I analyzed how the posing of higher order questions led to improved understandings among students of the problems being posed to them. This was important because the effectiveness of posing higher order questions must go beyond merely posing such questions to students. The relationship that develops as a result of the conversations around these questions is more important. You have to be able to see what kind of conversations evolve as a result of the questions that the teacher is posing to effectively evaluate the impact of higher order questions. We need to be able to answer the question of how the posing of higher order questions influences the learning environment and students’ thinking.

*Quantitative Data*

Lastly, a pre- and post-teacher questionnaire was administered to participating teachers. The purpose of this questionnaire was to get a sense of the importance that teachers ascribe to higher order questioning, and their self-perceptions of the level of questioning that they pose during math instruction. A total of 9 pre-surveys were administered to participating teachers of which 8 teachers completed them. In the post-round, a total of 7 surveys were distributed, 6 of which were returned. There were a total of 5 matched pair surveys from pre
to post that were completed by teachers.
DATA ANALYSIS AND RESULTS

The analysis and results of this study are organized into a qualitative and quantitative section. A brief description of the analysis conducted is presented along with a thorough interpretation of the results that were found from each data source. The connection of the results to the overarching research questions is also included.

*Qualitative Data*

Multiple sources of qualitative data were collected to capture the nuances in the development of student problem-solving skills over the duration of the CGI intervention and the evolution of the skill in questioning that teachers used in classroom instruction. Data collection included classroom video-tapings of instruction at three points in the semester; the beginning, the middle and the end. Pre- and post- student work samples on problem-solving scenarios were also collected to evaluate the nuances in terms of how their approaches to problem-solving evolved over the course of the semester. Lastly, the seven teachers who persisted over the course of the study were interviewed at the conclusion of the study to provide information regarding their opinions of the professional development that they received; to what degree CGI can be a part of their instruction, my role as the researcher and their assessment of their degree of implementation.
Classroom Videotaping

Widespread Teacher Practices

The analysis of classroom videotapes revealed that teachers are more frequently presenting story problems as the basis for math instruction. Every teacher across grade levels presented story problems on the days that they were recorded. In some instances, teachers posed multiple story problems during the recorded lesson. Teacher 3B, for example, posed a total of 5 story problems during the third round in which he was recorded.

Another frequent and consistent practice across all teachers and grade levels was asking students to explain their thinking on a much more frequent basis during instruction. This was a predominant strategy that manifest across all three rounds of recording. In the first recording of Teacher 2C, she was recorded posing the following questions to a group of students:

“How did you guys come up with your solution? What did you do to get that answer?”

In the second round of recordings, Teacher 2B also demonstrated evidence of eliciting student thinking as they are engaged in problem-solving:

Teacher 2B: “And can you explain to us what these numbers mean? 
Student: “The cookies.”

Teacher 2B: “And what does the 15 stand for?”

Teachers also consistently emphasized that there are multiple ways to solve a problem and encouraged their students to do so. In the final recording for Teacher 4C, he emphasized to students how they would be using multiple strategies to solve math problems as he went over the day’s learning objectives.
with his students. Teacher 3B also communicated in his final recorded lesson that his students are to use math strategies of their choice to solve their story problems, whether that is through using pictures, fact families, words, etc.

*Scattered Teacher Practices*

There was greater variation on different codes between teachers in terms of their practice in this study. The use of teacher-centered instructional strategies continued to be a part of teacher practice in different classroom. Teachers 2A and 2B used a highly guided instructional methodology in the first round of recordings. Teacher 2B comes with background in training in Singapore Math. The strategies that this teacher implemented required students to use a very specific framework as they engaged in problem solving. Teacher 2A does a lot of planning with Teacher 2B and they shared this required framework with their students in the first recording of their instruction. Teacher 2A, for example, posed the following story problem to her students:

*During P.E. Student X did 150 jumping jacks. Student B did 125 jumping jacks. Who did more?*

Students followed a prescribed framework requiring them to state *who* the problem is about, *what* they are doing in the problem, draw a base-10 block representation of the numbers in the problem, and finally state their answer. This practice was most pronounced in the first round of videotaping but tapered off over the next two instructional rounds.

A teacher-centered approach to instruction was also evident in the second and third recordings of 3rd and 4th grade teachers. The specific teacher-centered
approach that was evident was the tendency to pose de-contextualized, non-story problems in benchmark testing format in some cases. For example, in entering a recording session for Teacher 3C, problems such as the ones below were posted on the board:

1. 46,325 + 5,894  
2. 8,605 – 595  
3. 6 x 4  
4. 12/4

Similarly, Teacher 4A had *Quick Review* problems that students would have to complete similar in structure to those presented for Teacher 3C. There still is a preoccupation with ensuring that students are *testing ready*. Having students *test ready* has implications for grounding math instruction on a problem-solving foundation.

Lastly, although teachers have begun to pose questions prompting student thinking with much greater frequency, checking for individual understanding to ensure students are grasping the learning is inconsistent. As demonstrated by the short segment of Teacher 2C above, students are being asked to explain their thinking, but often times follow up questioning and dialogue does not persist to ensure student learning. For example, in the final videotaping of Teacher 3B, students were given ample problem-solving opportunities as they rotated between 4 problems in small groups that were posted on chart paper throughout the class. They were also given instructions that they can solve the problems in any way that they chose, but there was infrequent checking for understanding as students engaged in group problem-solving. Another example with Teacher 2B followed him providing students many opportunities to come up and share how they solved a particular problem. When he asked the student to explain her process and what
different numbers in the problem represented, the student shrugged her shoulders.
The teacher then proceeded to tell the student that she did a good job and had her go back to her seat. The teacher maintained a positive tone, but the interaction indicated the infrequency with which individual student understanding is checked. In some instances, lack of routines and procedures as well as struggles with classroom management hampers implementation of CGI instruction.

Student Problem-Solving Behaviors

The preferred problem-solving strategy that students used throughout this study was *direct modeling*. Direct modeling strategies consists of constructing direct models to represent a story problem situation. Students most often made drawings to represent the problem scenario to assist them in solving it. For example, Teacher 3C posed the following problem to her students to work on in small groups.

*Nine polar bears had 2 cubs this winter. How many bear cubs is that all together?*

One group of students began to draw images of bears. They then drew two circles underneath each bear to represent the problem. Another group drew nine circles and placed two dots inside of each circle.

Second graders demonstrated similar strategies in their problem-solving. Teacher 2B posed the following problem to his students in the second recording of the semester:

*Blake took out 3 bags when he was making cookies. After the cookies were done, he put 5 cookies in each bag. How many total cookies did Blake make?*
One student drew three rectangles with 5 cookies drawn inside of the rectangles.

Another interesting phenomenon related to student solution strategies was hybrid strategies. Hybrid strategies are those where students would use a combination of the direct modeling, counting up or derived number fact strategies described in the CGI framework. There were some students whose level of sophistication with number sense allowed them to be more efficient in their problem solving. Even with this sophistication, however, the students would still incorporate some form of direct modeling into their problem solving efforts. For example, in the above cookies problem about Blake, one student drew three rectangles to represent bags, and five circles inside of the rectangles to represent the cookies. The student then wrote the number sentence $5 + 5 + 5 = 15$. Even though this student understood that this problem could be solved with repeated addition, a picture was included with the number sentence. Another student did something similar but included the number sentence $3 \times 5 = 15$.

Student problem-solving efforts were also rife with misconceptions. Many of the students recorded showed evidence of not fully understanding the question being asked. Using the problem on Blake’s cookies and the polar bears as examples, it was not uncommon to see students just apply a random operation to the numbers presented in the problems. For example, some students wrote the number sentence $9 + 2 = 11$ as their solution for the nine polar bears having two cubs each. Another group of students got an answer of 27 total cubs after counting the 18 circles that represented the cubs plus the nine mama bears. In the problem involving Blake placing 5 cookies in 3 bags, many students in all 2nd
grade classes including Teachers 2A, 2B and 2C came up with answers of 8 by simply adding 5 + 3. Some students even included a drawing of 3 cookies plus 5 cookies for a total of 8 cookies. These widespread misconceptions were more common in the 2nd and 3rd grades. This was indicative of the need to engage in more one on one questioning to ensure student understanding which was lacking in classroom interaction in many classes.

The predominance of direct modeling strategies to solve problems was accompanied by a low incidence of students using derived number facts or number sense strategies to solve problems. This was consistent with struggles that we have seen in our district achievement related to number sense on our AIMS test reports. Another possible factor is how students are interpreting their teachers’ instructions to show their work. There were instances of teachers telling students that they need to show their work, often by drawing a picture. Teacher 2A, for example, had stated as one of her objectives that students would solve word problems by drawing a picture and a number sentence.

Student Work Sample Analysis

A total of 47 student work samples were selected to analyze using the problem-solving rubric presented in Appendix B. The rubric was designed to measure the following four elements in student problem-solving: extent of work shown, presence of mathematical representations, persistence (in problem-solving) and depth of reasoning. Each of these constructs was labeled Element 1, Element 2, Element 3 and Element 4 respectively. Each element had a possible score ranging from 0 up to 3; 0 being the lowest possible score. The descriptor of
what constitutes a 0, 1, 2 or 3 is presented for each element in Appendix B. A series of tables were constructed to evaluate the change in problem-solving that students demonstrate from the beginning of this study to the end. Each teacher selected their own pre and post problems to give to students. This decision was made so that teachers were choosing problems that were most relevant to their current standards that they were teaching.

This decision made evaluating pre to post gains quantitatively using the rubric a challenge. The reason it was challenging is going back to one of the main principles of Item Response Theory (IRT); not all questions are created equal. Some questions are more difficult than others. Stating that more students scored 2s and 3s on the rubric on the post work sample compared to the pre must be approached with caution as it is possible that the post question was easier than the pre question. Some examples from this study are presented here to illustrate.

Table 8

*Teacher 2A: Pre to Post Rubric Ratings on Student Work Samples: n=16*

<table>
<thead>
<tr>
<th>Problem Type</th>
<th>Compare</th>
<th>Separate Change Unknown</th>
<th>Multiplication</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rubric Category</strong></td>
<td>Timing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extent of work</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Shown</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Math Represent-</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>actions</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Persistence</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Depth of Reason-</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ing</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
As shown in Table 8, the work samples of 16 students from the classroom of Teacher 2A show that students were successful in solving the compare pre-problem and the post multiplication problem; all students scoring 2s and 3s on each element in the rubric. However, when the students had to work out a separate change unknown problem, they did not perform as well on the rubric. Each problem is shown below to demonstrate the differences in difficulty across the problems represented by Table 4.

**Compare Problem:** Student X did 150 jumping jacks. Student Y did 125 jumping jacks. Who did more jumping jacks?

**Separate Change Unknown Problem:** My mom found 16 coins in her purse. She gave some to me so I could practice counting change. Now she only has 6 coins left. How many coins did she give me?

**Multiplication Problem:** Miss T. made cookies for the holidays. She took out 4 containers to put some Holiday cookies in. She put 6 cookies in each container. How many total Holiday cookies did Ms. T. make?

The performance of the 16 students in the classroom of Teacher 2A suggests that students grasp with greater ease more straightforward story problems such as the compare and multiplication problem. The compare problem was highly guided by the teacher in terms of requiring the Singapore Math framework that was being required of students early in the year.

The success on multiplication problems generalized across grade levels. As seen in Table 5 for Teacher 2A, 15 of her students scored 3s across elements on the problem-solving rubric and the remaining 1 scored a 2. Based on the language of the rubric, this indicates that these 15 students demonstrate strong
depth of reasoning and use mathematical representations as evidence of this depth.

Teachers 3B and 3C demonstrate similar success with their students. Table 9 represents student performance on the problem-solving rubric for the students of Teacher 3C.

Table 9

<table>
<thead>
<tr>
<th>Problem Type</th>
<th>Join Result Unknown</th>
<th>Partitive Division</th>
<th>Multiplication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rubric Category</td>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>Extent of work Shown</td>
<td>0 1 1 6</td>
<td>0 0 1 7</td>
<td>0 0 2 6</td>
</tr>
<tr>
<td>Math Representations</td>
<td>0 1 1 6</td>
<td>0 0 1 7</td>
<td>0 0 2 6</td>
</tr>
<tr>
<td>Persistence</td>
<td>0 1 1 6</td>
<td>0 0 1 7</td>
<td>0 0 2 6</td>
</tr>
<tr>
<td>Depth of Reasoning</td>
<td>0 1 1 6</td>
<td>0 0 1 7</td>
<td>0 0 2 6</td>
</tr>
</tbody>
</table>

As seen for Teacher 3C, her students also demonstrate successful performance on rubric elements for the multiplication problem; two students scoring a 2 on the rubric and six students scoring a 3 on the rubric. Focusing on Element 2, this translates into the six students using mathematical representations to illustrate in depth understanding of the problem in context. The other two students use mathematical representations to indicate a basic understanding of the problem in context. The high rates of success on the partitive division problem also suggest that students are grasping with solid understanding the problems being posed to them and being able to represent the problem conceptually to
solve. The 3 students whose work samples were analyzed in the class of Teacher 3B also demonstrated solid conceptual understandings of multiplication problem types. All three of them scored 3s across the four elements in the rubric. The problems that students were posed by Teachers 3B and 3C were as follows:

Teacher 3B and 3C (Pre): Kenny had 9 ducks. Joe gave him 6 more ducks. How many ducks does Kenny have all together?

Teacher 3B and 3C (Post): Maria bought a sheet of stamps. The sheet has 4 rows. Each row has 6 stamps. How many stamps did she buy?

Teacher 3C (Post): The librarian wants to display 35 books. She plans to place 5 books on each shelf. How many shelves does she need to show all of her books?

The students of Teacher 4A showed similar success on a multiplication story problem with all 6 of her students with matched pair work samples scoring 3s across the rubric. Teacher 2C had 4 of her 6 students score 3s across the rubric on a multiplication story problem as well.

Students’ use of various strategies for solving problems favored the use of direct modeling. Students frequently drew pictures to represent the problem situation as described in earlier examples. Table 10 demonstrates the frequency with which students utilized various solution strategies pre to post. Use of direct modeling strategies started out high with 71% of student work involving some form of drawing or concrete representation. This increased to 83% in the post work samples. Counting strategies actually decreased while derived number fact strategies remained consistently low.
Table 10

Student Solution Strategy Distribution for n = 47 Work Samples

<table>
<thead>
<tr>
<th>Solution Strategy Used</th>
<th>Pre-Recording Frequencies</th>
<th>Post-Recording Frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Modeling</td>
<td>39 (71%)</td>
<td>67 (83%)</td>
</tr>
<tr>
<td>Counting Strategies</td>
<td>7 (13%)</td>
<td>1 (1.2%)</td>
</tr>
<tr>
<td>Derived Number Facts</td>
<td>9 (16%)</td>
<td>13 (16%)</td>
</tr>
<tr>
<td>Totals</td>
<td>55</td>
<td>81</td>
</tr>
</tbody>
</table>

Teacher Questioning

Evaluating the effect that CGI had on the questions teachers pose during math instruction was done by classifying questions posed by teachers into a Bloom’s Taxonomy matrix and administering a survey to participating teachers. The survey focused on the importance that teachers ascribe to higher level questioning during instruction and their self-evaluation of the degree to which they do this.

Higher Level Questioning Matrix

The matrix presented in Table 11, adapted from Caulfield-Sloan and Ruzicka (2005), was used to establish a pre to post table of frequencies on the types of questions that teachers were posing during math instruction. The researcher watched the videos that were taken to analyze student work on problem-solving tasks. From these videos, instructional questions that teachers posed during the videotaping were selected for classification using this matrix.

An instructional question is one, which would be considered academic in nature. An example might be what is the coefficient of y in the expression 3y + 17? A non-instructional question could be, alright class, are we all ready to begin? The
instructional questions from the first round of recordings were transcribed and classified across the 6 levels in Bloom’s Taxonomy. This process was repeated for the final video tapings, which were deemed the post observations.

Table 11

Matrix of Questions Posed Pre- to Post- Using Bloom’s Taxonomy

<table>
<thead>
<tr>
<th>Teacher Name</th>
<th>Knowledge</th>
<th>Comprehension</th>
<th>Application</th>
<th>Analysis</th>
<th>Evaluation</th>
<th>Synthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Teacher 2A</td>
<td>3</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Teacher 2B</td>
<td>12</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Teacher 2C</td>
<td>3</td>
<td>11</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Teacher 3B</td>
<td>0</td>
<td>11</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Teacher 3C</td>
<td>9</td>
<td>11</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Teacher 4A</td>
<td>7</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Teacher 4C</td>
<td>6</td>
<td>26</td>
<td>1</td>
<td>4</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Totals:</td>
<td>40</td>
<td>72</td>
<td>5</td>
<td>8</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

To validate the process of classifying questions using Bloom’s Taxonomy, a field test was conducted in the Spring of 2011 with members of the Curriculum and Instruction team and Superintendent of the Tolleson Elementary School District. At that time, a total of 111 questions posed by teachers were analyzed and the vast majority were classified as knowledge level questions according to Bloom’s Taxonomy. Examples of such questions are illustrated in the instructional segments recorded in this study by Teachers 2B and 4C:

Teacher 2B: What does the H stand for in our chart? Student: Hundreds.

Teacher 4C: What does the Aunt stand for in Please Excuse My Dear Aunt Sally?

Student: Addition.
These would be questions that require mere recall of facts at lower levels of cognition. Pre to post across grade levels, it is evident that a majority of questions posed are at the knowledge level.

Notable in this matrix is how Teacher 2C saw increases in both the frequency of knowledge level questions posed and analysis level questions. In the post recording, Teacher 2C for the first time had students come up to the board to explain their solution to their peers. This posed a great opportunity for the teacher to be able to pose a variety of questions to students as they explained their reasoning.

Teacher 2B also asked a high degree of knowledge level questions in the first round of recordings. Many of the questions were related to the Singapore Math framework that the teacher was using with students. Some examples of questions posed follow below:

*Who is another character in our story problem?*
*What does the T stand for in our chart?*

Teacher 4C drastically increased the frequency of knowledge level questions in the final recording of instruction. During this lesson, the problem-solving procedure became highly guided and prescribed by the teacher. Two story problems were done with teacher guidance prior to the students working independently on a third problem. Some of the questions posed by the teacher during this lesson were as follows:

*What are the four basic operations?*
*What information do we know? What information do we have?*
Teachers 3B and 2A asked a relatively few amount of questions during recordings. Part of this could be due to the fact that CGI calls for students to be posed with story problems and to develop solutions in their own creative ways rather than the teacher showing them steps to solve. This can easily be internalized as a *laissez-faire approach* to facilitating, meaning that students are left to engage in problem-solving with minimal teacher intervention. Teacher 3B greatly increased the number of knowledge level questions posed in the final round of recordings. Most of these questions stemmed from the teacher making the point that there are multiple ways to solve a problem. He posed a series of questions eliciting from students some of the various strategies that can be used to solve a problem.

Overall, the frequency of analysis level questions increased compared to the initial field testing conducted in the Spring of 2011. This is due to the fact that teachers are asking with much greater frequency for students to explain their answers.

*Teacher Questioning Survey*

A survey was administered to 9 teachers at the outset of the study and the 7 teachers who remained at the end of the study. Between the administration of the pre and post surveys, a total of 5 matched pairs were returned. It was these 5 pairs that were used in the analysis of teachers’ responses to the surveys. The first two items of the survey asked teachers for demographic information including the range of years of teaching experience that they have and their range of grade levels in which their primary experience resides. After the demographic
questions, there are 5 items related to the degree of importance that teachers attach to higher level questioning in instruction. The next 5 questions address the degree to which higher level questioning is a part of the teacher’s instructional practices.

To ensure reliability of the survey tool, a field test was conducted with 8 teachers in the Spring of 2011. From this field test, a Cronbach’s Alpha value of 0.846 was established. Appendix E contains a copy of the survey tool. Table 12 summarizes the pre and post responses of the 5 matched pair teachers who took the survey.

Table 12

*Teacher Questioning Survey Analysis: n = 5*

<table>
<thead>
<tr>
<th>Question Number</th>
<th>Pre- Mean &amp; SD</th>
<th>Post Mean &amp; SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q3</td>
<td>4.0(0.0)</td>
<td>4.4(0.55)</td>
</tr>
<tr>
<td>Q4</td>
<td>4.4(0.55)</td>
<td>4.6(0.55)</td>
</tr>
<tr>
<td>Q5</td>
<td>4.2(0.44)</td>
<td>4.6(0.55)</td>
</tr>
<tr>
<td>Q6</td>
<td>3.4(0.55)</td>
<td>3.4(0.55)</td>
</tr>
<tr>
<td>Q7</td>
<td>4.2(0.44)</td>
<td>4.2(0.44)</td>
</tr>
<tr>
<td>Q8</td>
<td>3.5(1.29)</td>
<td>4.0(0.71)</td>
</tr>
<tr>
<td>Q9</td>
<td>3.4(0.55)</td>
<td>3.4(0.55)</td>
</tr>
<tr>
<td>Q10</td>
<td>3.8(0.84)</td>
<td>4.2(0.84)</td>
</tr>
<tr>
<td>Q11</td>
<td>3.6(0.55)</td>
<td>4.0(1.0)</td>
</tr>
<tr>
<td>Q12</td>
<td>3.4(0.55)</td>
<td>4.0(0.71)</td>
</tr>
</tbody>
</table>

*Note: 1 = Strongly Disagree, 2 = Disagree, 3 = Somewhat Agree, 4 = Agree, 5 = Strongly Agree.*

Teacher responses to question numbers 3 through 7 generally indicate that they ascribe high importance to higher level questioning in instruction. There were mean gains in questions 3, 4 and 5 along with relatively small standard deviations. Taking number 3 as an example, when teachers first took the survey, their mean response was a 4.0 with no standard deviation meaning that they
unanimously agree with the notion that it is important to pose questions during instruction at the higher levels of Bloom; no lower than the application level.

Mean responses to question number 6 were interesting in that there was no change from pre to post. Question 6 read as follows:

*Due to the time consuming nature of higher level questioning in instruction, it should be used occasionally to allow for greater content coverage.*

Teachers in this sample indicated that they somewhat agreed with this statement. This does not come as a surprise as teachers are faced with high pressures in terms of accountability for performance on state tests. Informally, widespread sentiment is often communicated about how are we as teachers to get through all of the standards by April.

Questions 8 through 12 addressed the degree to which teachers believed that higher level questioning was a part of their classroom instruction. Notable gains can be seen in Table 12. For example, pre to post responses for question 8 show an increased mean from 3.5 to 4.0 and a corresponding standard deviation decrease from 1.29 to 0.71. This means that teachers increased in their level of agreement with the statement and with greater consistency between teachers in the sample. Question 8 read as follows:

*I carefully plan for the inclusion of higher-level questions in my math instruction.*

Teachers are reporting that their questioning levels have become a greater consideration in their instructional planning.
Interestingly, responses did not change pre to post for question 9.

Question 9 read as follows:

_The majority of questions that I pose during math instruction are at the higher levels of Bloom’s Taxonomy (Application, Analysis, Evaluation and Synthesis)._ 

This stands in contrast to the mean increase seen for question 8 which suggested that planning for higher level questioning in instruction is something considered carefully in planning.

Teacher Interviews

A total of 7 teachers were interviewed who stayed with the study from the beginning to the end. Eight total questions were asked of the teachers around their perception of the CGI philosophy, training, and the researcher’s role as a former principal and their levels of implementation in their classroom.

Each interview was transcribed verbatim and analyzed for themes. Each transcription was read through in its entirety to identify some initial themes. Next, the transcriptions were read one question at a time for each of the interviewees. Looking at responses to questions one at a time, open coding was used to establish codes seen in the codebook in Appendix F. These codes were used to help articulate the results of the survey presented here.

The first question in the survey dealt with what teachers’ impressions of the CGI training were to date. The feedback was unanimously positive but for various reasons. Some of the teachers mentioned how they appreciated that the training has helped them place a greater focus on analyzing students’ thinking. Teacher 4C, for example, expressed how he appreciated that the training
emphasized analysis of student thinking and not just students spitting out an answer to get back to the teacher. They also eluded to how it was appreciated that CGI was helping them prepare for the common core standards. Teacher 3C reported that she has seen students improve at navigating open ended problems over time which stood in contrast to them just wanting answers at the beginning of the semester. Overall, feedback on the training was positive. Teacher 4A did express a desire to see more rigorous examples of problems while Teacher 2C expressed a desire to have more time in the classroom to implement the ideas.

Another major theme from the interviews was the need for resources to support implementation. When asked about what would be included in an ideal math professional development, both Teachers 4A and 4C eluded to professional development that would include ways to find resources to pose quality story problems. Teacher 4C mentioned that our current text materials do not do an adequate job of this and how time consuming it is to create problems on your own. Teacher 4A also expressed a desire to have professional development that will help her find more resources to implement CGI.

The question of how frequently CGI should be implemented in instruction was also a major theme of the interview. All teachers were in consensus that it should be done at least weekly. Teachers 3B, 2B, 4A and 2C stated that ideally it would be included as part of daily mathematics instruction. Some teachers also brought up challenges to meeting such ideals for implementation. Teachers 3C and 3B both eluded to the fact that students need to have basic skill foundations before they can engage in complex problem-solving on a routine basis. Teacher
3C expressed the need for having a balance of traditional, teacher-centered instruction with the more student-centered approach of CGI as some students are lacking basic skill foundations. Teacher 3B also mentioned how students had never seen division before and were not familiar with number sentences such as 15/3 or vocabulary associated with division. He felt that it was important to frontload such information with students before taking them to problem-solving applications with the skill.

Many teachers rated their level of implementation of CGI in their instruction as still developing. Teachers 3B and 4A rated their implementation on a 10 point scale as being somewhere in the middle. Teacher 2A mentioned that implementation of CGI through the use of manipulatives is challenging because the learning environment becomes chaotic when students begin using these resources. Teachers 2B and 2C also mentioned the challenges that come with having to cover so much content.

Another important factor of interest in the interview was the influence that the researcher had on implementation of CGI. The researcher was the principal of P.H. Gonzales Elementary School for the past six years. This fact had to be navigated carefully in coming into the environment as an outside researcher. Teachers unanimously reported that the researcher’s role did not adversely or negatively affect their implementation of CGI into their instruction. Teachers 3B and 2B mentioned that they are open to any professional development that will help to improve teaching and learning regardless of who is leading the effort. Teachers 4A and 3C saw the researcher very much as a neutral observer. Teacher
3C said that she would have done this for any other students as well. Teachers 4C and 2A mentioned that they were comfortable with the researcher from having established a positive relationship from their prior work history.

Quantitative Data

Archival Time Series

The archival time series included 6 data points for each of the 2nd, 3rd and 4th grade cohorts of students at P.H. Gonzales Elementary School. The first 4 points in the series represent the mean standardized scores for a given cohort before CGI training was ever applied. The last 2 points in the series represents the mean standardized scores for the cohorts under study after having received CGI training. Expected points were also computed to forecast what we could have expected without CGI training. The results for each cohort are discussed below.

Figure 1 shows a graphic representation for the archival time series for the current year 2nd graders who were a part of this study from P.H. Gonzales Elementary School. The blue line shows what we could have expected based on this cohort’s achievement trend from last year’s math benchmark assessments. Pre-CGI we were seeing a modest increase in standardized mean scores for the current year 2nd grade cohort of students. As the time series shows, what actually happened diverges from what was expected to happen. A downward trend in terms of mean standardized scores is showing for the Fall 2011 semester.
The significance of the difference between the actual means and expected means computed from linear regression were tested using t-tests. It is desirable to see if the differences between these values are significant or just due to chance.

Figure 1.

Archival Time Series for Current-Year 2\textsuperscript{nd} Graders from P.H. Gonzales Elementary School

![Time Series 1st-2nd Grade Cohort: 2010-2012](image)

The time series for current year 3\textsuperscript{rd} graders for P.H. Gonzales Elementary School showed a more promising trend in terms of comparing actual achievement after CGI and what was expected in the absence of CGI based on linear regression. The actual standardized means are beginning to show an upward trend, whereas the expected trend based on last year’s achievement was downward. The significance of this difference was also determined using t-testing.
The time series for current year 4th graders also shows that after the beginning of CGI training, standardized mean scores begin trending upward. This upward trend outpaces the downward slope of the expected values, but the actual achievement shows a dip after an initial spike in gains. The significance of the differences between the expected and actual time series was determined through t-testing.
In 2 of the 3 cohorts examined in this study, the archival time series shows achievement gains relative to the expected trend line. This is the case for current year 3rd graders and 4th graders. Our 2nd grade cohort showed a trend that declines relative to the expected achievement based on last year’s achievement outcomes on quarterly math benchmark testing. To determine the degree of significance of these differences, a series of six t-tests were conducted to compare the actual standardized mean to the expected standardized mean at the 5th data point and 6th data point for each of our three grade level cohorts. The results are presented in Table 13.
Table 13

*Significance of Differences in Achievement: Actual v. Expected Outcomes*

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>Fall 11 BM</th>
<th>Winter 11 BM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Expected M</td>
<td>Actual M</td>
</tr>
<tr>
<td>2nd Grade</td>
<td>0.14</td>
<td>-0.43</td>
</tr>
<tr>
<td>3rd Grade</td>
<td>-0.92</td>
<td>-0.47</td>
</tr>
<tr>
<td>4th Grade</td>
<td>-0.76</td>
<td>0.02</td>
</tr>
</tbody>
</table>

*Note: BM = Benchmark Test. p < 0.05*

The differences on all six t-test were deemed significant as a t-test at the .05 significance level with 84 and 80 degrees of freedom produces a critical value of 2.0. All t-values exceeded this critical value in magnitude. What this means is that in 3rd and 4th grade we are seeing statistically significant gains relative to what was expected from the linear regression model. This has to be read cautiously, however, in 4th grade as Winter benchmark scores showed a decline following an initial spike on the Fall 2011 math benchmark assessment.

The decline being experienced by the 2nd grade cohort of students was also deemed statistically significant. This indicates that this decline is likely not just due to chance.

To validate the results of these time series, it is important to minimize the threat of nonequivalence or the possibility that any of these cohorts has an inherent achievement advantage over the other. To do this, a t-test for dependent samples was conducted for current year 2nd graders, 3rd graders and 4th graders. Their Fall 2010 to Winter 2010 mean growth scores were evaluated to determine if any one cohort made statistically significant greater growth than another group. Table 14 illustrates the results of this analysis.
Table 14

Fall 10 to Winter 10 Growth Comparisons

<table>
<thead>
<tr>
<th>Grade Level</th>
<th>M(SD)</th>
<th>t(df)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Grade</td>
<td>-0.04(0.73)</td>
<td>0.57(96)</td>
<td>0.57</td>
</tr>
<tr>
<td>2nd Grade</td>
<td>-0.13(0.70)</td>
<td>1.80(98)</td>
<td>0.08</td>
</tr>
<tr>
<td>3rd Grade</td>
<td>-0.17(0.62)</td>
<td>2.65(90)</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Note: *p < .05

Based on the results of this analysis, nonequivalence can be ruled out between current year 2nd and 3rd graders. Neither p value was under .05 indicating that the .04 and .13 respective declines were not deemed statistically significant and possibly just due to chance. Although, the 2nd grade Fall to Winter decline was more significant than that of the 1st graders. There is a nonequivalence threat for the current year 4th graders based on this analysis as their .17 declines was deemed statistically significant according to the p-value of .01. This did not factor in to the time series as current year 4th graders performed better than what would have been expected based on their trend line.

Dissimilar Cohorts Comparison

A final stage in this analysis was to triangulate any significant findings in the archival time series by comparing the gains made by last year’s 2nd, 3rd and 4th graders who did not have CGI, with this year’s 2nd, 3rd and 4th graders who have had some CGI instruction. Table 15 shows the results of these comparisons and the degree of significance in gains or declines comparatively.
Table 15

Dissimilar Cohort Growth Comparisons: 2010-11 v. 2011-12 Fall Growth

<table>
<thead>
<tr>
<th>Grade</th>
<th>2010 M(SD)</th>
<th>2011 M(SD)</th>
<th>2010 t(df)</th>
<th>2011 t(df)</th>
<th>2010 p</th>
<th>2011 p</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd</td>
<td>-0.13(0.7)</td>
<td>-0.10(0.65)</td>
<td>1.80(98)</td>
<td>1.41(83)</td>
<td>0.08</td>
<td>0.16</td>
</tr>
<tr>
<td>3rd</td>
<td>-0.17(0.62)</td>
<td>0.002(0.57)</td>
<td>2.65(90)</td>
<td>-0.32(84)</td>
<td>0.01</td>
<td>0.97</td>
</tr>
<tr>
<td>4th</td>
<td>0.02(0.65)</td>
<td>-0.23(0.72)</td>
<td>0.35(85)</td>
<td>2.96(80)</td>
<td>0.72</td>
<td>0.004</td>
</tr>
</tbody>
</table>

This data indicates that both the 2010 and 2011 2nd grade cohorts experienced declines in their mean math scores from Fall to Winter; -0.13 and -0.10 standardized units respectively. In neither case, were these declines deemed to be statistically significant.

For the 3rd grade cohorts, the 2010 group experienced a statistically significant decline in Fall to Winter growth of -0.17 standardized units. This year’s 3rd grade cohort actually experienced a Fall to Winter mean score gain of 0.002 standardized units which was not deemed statistically significant. In comparison, the 2011 3rd graders made a statistically insignificant gain while 2010 3rd graders had a statistically significant decline.

Lastly, 2010 4th graders fared better than 2011 4th graders as they achieved a statistically insignificant gain of 0.02 standardized units in their mean scores from Fall to Winter. This year’s 4th graders, although outperforming the expected trend line, experienced a statistically significant decline from Fall to Winter with a drop of -0.23 standardized units.
Chapter 5

DISCUSSION

This chapter articulated assertions based on the results of the data collected over the course of this study. These assertions are the overarching conclusions that have been reached as a result of this research. This section will also explain the limitations of this study, and implications for teacher practice and policy.

Assertions

A total of 7 assertions were gleaned from the data that was collected over the course of this study. The following section articulates each of these assertions and the evidence that supports them.

Assertion 1: Participating teachers provided more frequent problem-solving opportunities to students as the basis for instruction.

The abundance of literature about the 21st century learner suggests that problem-solving is an essential skill (NCTM, 2006). Furthermore, frequent opportunities for students to engage in open-ended problem-solving where there is not a pre-determined solution is promoted as a strategy to develop this essential competency in our students so that they can become independent thinkers (NCTM, 2006; Polya, 1945). Dewey (1916) poignantly conveys a parallel point when he describes “good breeding,” or “good manners” as being acquired through “habitual action in response to habitual stimuli; not by conveying information.” Although this reference is framed in the context in the development of manners, the applicability to the disposition of problem-solving remains relevant. The
development of the 21st century learner who is a proficient problem-solver must come from frequent opportunities to become such a problem-solver. In essence, we want to develop the habit of problem-solving which comes through frequent posing of open-ended problems to students empowering them to solve creatively using their background and experience.

Initial remnants of these frequent opportunities began to manifest in video recordings. Every teacher in each round of the three recordings posed a story problem for students to work through. The structure and format in which students worked on the problem varied from classroom to classroom. In some classrooms, students worked on these problems in small groups or pairs. In other classrooms, students worked on the problems individually. For example, Teacher 2A had her students work on the story problem in the third and final recording independently to see the different ways in which they solved. Below are two examples of story problems that were posed during the instructional recordings; one from 2nd grade and one from 3rd grade:

2nd Grade Example: Blake took out 3 bags when he was making cookies. After the cookies were done, he put 5 cookies in each bag. How many total cookies did Blake make?

3rd Grade Example: Nine polar bears had 2 cubs this winter. How many bear cubs is that all together?

In some instances, teachers posed multiple story problems during the instructional video recordings. For example, in the third and final recording of Teacher 3B, he had small groups of students rotate between a total of 5 story problems that were
posted throughout the classroom. The posing of story problems was consistent for each teacher across each instructional round of video recordings.

A notable finding in relation to a later assertion was the issue of instructional resources. While teachers are finding more frequent opportunities to incorporate problem-solving into their instruction, they note similar challenges across several teachers in regards to resources. In the interview with Teacher 4C, he expressed that we are limited in quality resources that are available to consistently implement quality problem-solving opportunities. He stated that this limitation in resources creates a strain for teachers to create story problems on their own which becomes very time consuming. Furthermore, teachers responded in their interviews that they were conducting CGI instruction at least once per week in their instruction. Teacher 3C expressed that ideally math would be based in story problems daily. Teacher 4A expressed the same ideal of daily CGI instruction during math instruction.

Assertion 2: The focus of instruction has become about more than just a right or wrong answer.

Teachers across grade levels went beyond merely asking students for an answer and moving on if it was correct. The teachers in the study consistently asked students for explanations of how they arrived at an answer. Teacher 3C, for example, conveyed the following message as students prepared to solve the story problem posed to the class:

“You are going to get some paper. I want you to solve the problem. Don’t just write the answer.”
This practice became consistent across teachers and grade levels as indicated by the statements of various teachers below:

*Teacher 4C, Round 1:* “Why did you use pictures for? What do pictures help us do?”

*Teacher 4A, Round 3:* “Why would you say (c)? What’s your reasoning?”

*Teacher 2C:* “Explain what you were thinking. What were you thinking?”

The 2nd grade team of teachers also progressed from a teacher-centered to a more student-centered pedagogical style from the first round of recordings to the second and third rounds. In the first set of recordings, Teachers 2A and 2B demonstrated evidence of collaborative planning. They both had students using a framework that Teacher 2B learned in his experience and training with Singapore Math. They provided a very prescribed framework for students to follow as they engaged in problem-solving. Both Teachers 2A and 2B monitored student work as they engaged in problem-solving to ensure that students were following this framework and provided consistent praise for students who did so. The framework required students to construct base-10 block drawing representations of numbers, which reinforced place value skills. However, students did not have opportunities to solve the problem in their own creative way. The problem posed was the following from the classroom of Teacher 2B:

*During P.E. Anthony did 150 jumping jacks. Gabriel did 125 jumping jacks. Who did more?*

In later recordings, these same teachers provided students opportunities to use additional ways beyond the Singapore Math framework to solve their problems.
An interesting finding was that even with the empowerment to use more individualized strategies, many students still resorted to the initially prescribed framework to approach their problem-solving tasks. The framework that the teachers had the students follow was as follows:

1. Identify the characters or the who in your problem.
2. Specify the what in the problem, or what they are doing.
3. Build a base-10 block representation of your numbers.
4. Write your answer.

One student could be heard on video in the background when given an option to use a different strategy on a problem saying “who are the characters.” Many other students were also using the template that their teacher had trained them on.

Teacher 2A’s statement during the Round 3 recording also demonstrates the increased flexibility that was accorded to students in later rounds to approach the resolution of story problems in multiple ways:

“We are going to read through it together, but you are trying to work it out all on your own; whatever way is best for you.”

Interviews corroborate that teachers began to place a greater emphasis on how students worked on problem-solving scenarios as opposed to just evaluating an answer as right or wrong. Teacher 4C stated in his interview that he appreciates how the trainer challenges them to ask students to explain why and expressed concerns about students not wanting to show their work and just be done quickly. Teacher 3B also expressed in his interview that figuring out how kids think is what he has gotten the most out of in the trainings. In all of these
instances, teachers were emphasizing the importance of focusing on students’ problem-solving processes.

Teacher responses on surveys also support this assertion. There was a significant mean increase in the response of teachers about how carefully they plan for higher level questioning in their instruction from a mean of 3.5 to 4.0 on the Likert Scale. A 4 indicates a greater degree of agreement with the statement. Teachers also ascribed a high degree of importance to posing higher level thinking questions based on Bloom’s Taxonomy beyond mere recall questions.

These findings help to answer the research questions around how students’ problem-solving abilities change and how teacher questioning changes. As teachers have placed greater emphasis on students’ problem-solving processes, it is communicated by the act of teacher questioning that their ability to explain their answer and demonstrate their reasoning in their work matters. Furthermore, as teachers look beyond whether or not a student got a right or wrong answer and immediately move on, they necessarily ask more questions of students as demonstrated in the examples above.

Assertion 3: Students persisted in their use of direct modeling strategies as the predominant strategy for approaching word problems. The use of derived number fact strategies slightly increased over rounds but varied across grade levels.

Direct modeling strategies refers to the basic strategies that students use to problem-solve by using physical objects such as counters, drawing pictures, using their fingers, etc. (Carpenter et al., 1999). Derived number facts strategies refer
to problem-solving approaches where students use their understanding of relationships between numbers to arrive at a solution (Carpenter et al., 1999). For example, if a student is told that her brother has $12 and she has $9 and is asked how much money they have between the two of them, a derived number fact strategy might be the student expressing that 10 plus 10 is 20. Furthermore, 12 is 2 more than 10 and 9 is one less than 10, so the total is $21 between the two of them. This kind of reasoning illustrates a derived number fact strategy for problem solving.

Direct modeling strategies were commonly used across the three video recordings across grade levels. There were a total of 51 recorded instances of students having used such strategies. This does not imply that there were not more as there is great complexity and consideration in determining what to record when watching video segments of instruction.

Many teachers either directly or indirectly encouraged students to use a direct modeling strategy to solve their problems. For example, Teacher 4A in the word problem below, drew two bags as a model for how students could approach its resolution.

*A bag of Florida oranges contains 3 more oranges than a bag of Florida grapefruits. There are a total of 21 pieces of fruit in the two bags. How many more oranges are in the bag?*

Additionally, Teacher 2A in her third recording had the following learning objective listed on the whiteboard:

*I will complete a story problem by drawing a picture and writing a number sentence.*
Teacher 3C also made repeated references for students to show her what they did in their work. To triangulate this finding, a total of 47 pre and post student work samples were examined that included 136 story problems in total. Out of these 136 story problems, 112 solution strategies involved students using a direct modeling strategy to solve or attempt to solve the problem; typically by way of drawing a picture. In percentage terms, 82% of student work samples demonstrated that students used direct modeling strategies in their approaches to problem solving. The distribution of the types of solution strategies that students employed in their work samples is represented in Table 10 below.

Table 10

Student Solution Strategy Distribution for n = 47 Work Samples

<table>
<thead>
<tr>
<th>Solution Strategy Used</th>
<th>Pre-Recording Frequencies</th>
<th>Post-Recording Frequencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct Modeling</td>
<td>39 (71%)</td>
<td>67 (83%)</td>
</tr>
<tr>
<td>Counting Strategies</td>
<td>7 (13%)</td>
<td>1 (1.2%)</td>
</tr>
<tr>
<td>Derived Number Facts</td>
<td>9 (16%)</td>
<td>13 (16%)</td>
</tr>
<tr>
<td>Totals</td>
<td>55</td>
<td>81</td>
</tr>
</tbody>
</table>

An interesting nuance in the degree to which students used direct modeling strategies surfaced both in the examination of student work samples and in observing students work during recordings. There were several instances of students who had a strong sense and adeptness at using sophisticated number facts to solve problems. Several of these students would solve their problem using their knowledge of number facts through a more sophisticated strategy than direct modeling but would still include a concrete representation such as a drawing. The
following 2nd grade story problem from the classroom of Teacher 2A helps to illustrate this nuance.

*The teacher made cookies for the holidays. She took out 4 containers to put some Holiday cookies in. She put 6 cookies in each container. How many total Holiday cookies did the teacher make?*

A student resolved the problem using the counting up strategy as follows: \(6 + 6 + 6 + 6 = 24\). Accompanying the use of this counting up strategy, the student drew 4 rectangles with 6 circles inside of them representing the cookies as a concrete, direct model of the story problem. This is suggestive that students are interpreting their teachers’ directions to *show their work* as equating to making a direct model representation of the problem being posed. This phenomenon also applied with less rigorous problems. The 3rd grade problem posed on Round 1 of instructional recordings helps to illustrate this.

*Kenny had 9 ducks. Joe gave him 6 more ducks. How many ducks does Kenny have altogether?*

The use of derived number facts strategies was much more scant in this study. A total of 41 instances of students using such strategies were recorded over the course of the three instructional video recordings across grade levels. This number was spiked by the higher instances of number facts strategies utilized by students in the classroom of Teacher 3B and Teacher 4A in their final instructional recordings. Teacher 3B had provided students with a total of 5 word problems which is more than two times the typical provision of story problems presented during instruction. Increased story problems produced more student responses and consequently derived number facts strategies. Teacher 4A posed a
problem in the third round of recordings that was based on money which lent itself to solving using a more standard computation of monetary denominations.

The word problem is listed below.

*Will and Rita brought money with them to spend at the fair. Will had $6.60 more than Rita. Rita had 3 dollars, 2 quarters, 4 dimes, and 2 nickels. How much money did Will bring to the fair?*

The less frequent use of derived number facts strategies in problem-solving scenarios is consistent with our high stakes achievement results. Strand 1 in our Arizona State Standards which corresponds with number sense and numerical operations has shown achievement levels below state averages in this area and has arisen as a need on our quarterly benchmark assessments as well. These findings indicate that students’ approaches to problem-solving have remained with great frequency at direct modeling to represent problem-solving scenarios. This is not a bad thing as the idea with problem-solving is to get students to make sense of the situation being presented to them. Students’ use of *hybrid strategies* such as drawings and derived number facts suggests a need to differentiate our instruction based on the level of sophistication that a student may have with their number facts.

*Assertion 4: There were many misconceptions evidenced in students’ solutions indicating that students did not understand questions being asked in many of the story problems.*

One of the codes in Appendix C was labeled ST MISCON. This code represented the instances in which students attempted to solve a problem but
misunderstood what was being asked in the question. The following example from a 3rd grade classroom in the study can help to illustrate:

*Lesley took out 4 bags to put some pieces of Halloween candy. She put 8 pieces of Halloween candy in each bag. How many total pieces of Halloween candy did she have?*

Several students solved the problem by merely taking the two numbers in the problem and adding them together. Several students got an answer of 12 to this problem by completing the number sentence $8 + 4$. This strategy was seen from one of the student work samples that were collected for pre and post analysis.

Video recordings throughout rounds and across grade levels corroborated widespread misunderstandings of questions being posed in story problems. In the classroom of Teacher 3B in the second round of recordings, students obtained an answer of 11 by adding $9 + 2$ in response to the story problem posed below.

*Nine polar bears had 2 cubs this winter. How many bear cubs is that all together?*

The problem of frequent misconceptions in student reasoning is also corroborated in the pre to post work sample analysis presented in Appendix E of this study.

Tables 5 and 16 below represent the progression of student problem-solving practices based on the rubric presented in Appendix D. Some teachers posed one story problem for their pre story problem. Some teachers posed more than one pre story problem. The same was true for post story problems as well.

Additionally, the level of difficulty of problems posed also varied across teacher. Teachers were given independence to decide on the problems to pose so that the
content they furnished to students was on pace with their instruction and relevant to what they were learning at that point in time.

Table 5

*Teacher 2A: Pre to Post Rubric Ratings on Student Work Samples: n=16*

<table>
<thead>
<tr>
<th>Problem Type</th>
<th>Compare</th>
<th>Separate Change Unknown</th>
<th>Multiplication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing</td>
<td>Pre</td>
<td>Post 1</td>
<td>Post 2</td>
</tr>
<tr>
<td>Rubric Category</td>
<td>0</td>
<td>1 2 3</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>Extent of work</td>
<td>0 0</td>
<td>2 14</td>
<td>0 3 7 6</td>
</tr>
<tr>
<td>Shown</td>
<td>0 0</td>
<td>2 14</td>
<td>0 3 7 6</td>
</tr>
<tr>
<td>Math Representations</td>
<td>0 0</td>
<td>2 14</td>
<td>0 3 7 6</td>
</tr>
<tr>
<td>Persistence</td>
<td>0 0</td>
<td>2 14</td>
<td>0 3 7 6</td>
</tr>
<tr>
<td>Depth of Reasoning</td>
<td>0 0</td>
<td>2 14</td>
<td>0 3 7 6</td>
</tr>
</tbody>
</table>

Table 16

*Teacher 2B: Pre to Post Rubric Ratings on Student Work Samples: n=7*

<table>
<thead>
<tr>
<th>Problem Type</th>
<th>Compare</th>
<th>Separate Change Unknown</th>
<th>Multiplication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timing</td>
<td>Pre</td>
<td>Post 1</td>
<td>Post 2</td>
</tr>
<tr>
<td>Rubric Category</td>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
<td>0 1 2 3</td>
</tr>
<tr>
<td>Extent of work</td>
<td>0 0 2 5</td>
<td>0 6 0 1</td>
<td>0 0 1 6</td>
</tr>
<tr>
<td>Shown</td>
<td>0 0 2 5</td>
<td>0 6 0 1</td>
<td>0 0 1 6</td>
</tr>
<tr>
<td>Math Representations</td>
<td>0 0 2 5</td>
<td>0 6 0 1</td>
<td>0 0 1 6</td>
</tr>
<tr>
<td>Persistence</td>
<td>0 0 2 5</td>
<td>0 6 0 1</td>
<td>0 0 1 6</td>
</tr>
<tr>
<td>Depth of Reasoning</td>
<td>0 0 2 5</td>
<td>0 6 0 1</td>
<td>0 0 1 6</td>
</tr>
</tbody>
</table>
An important consideration in analyzing student ratings using this rubric was the problem type. Consistent with concepts from Item Response Theory, not all problems are equally difficult; some are more simple than others (Harris, 2011, p. 35). The CGI framework is based on various problem types, which differ in their level of complexity and cognitive demand on children. Table 4 illustrates the different problem types and an example of each type of problem.

Table 4

<table>
<thead>
<tr>
<th>Problem Types</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Join Result Unknown</td>
<td>Kenny had 9 ducks. Joe gave him 6 more ducks. How many ducks does Kenny have altogether?</td>
</tr>
<tr>
<td>Join Change Unknown</td>
<td>Julie baked 19 cookies. Her mother brought over some more cookies for the party. They took 31 cookies to the party. How many cookies did Julie’s mother bring for the party?</td>
</tr>
<tr>
<td>Join Start Unknown</td>
<td>Claudia has the most points scored this season on her basketball team. She scored 24 points in her last game. For the season, she has 362 points. How many points did she have before her last game?</td>
</tr>
<tr>
<td>Separate Result Unknown</td>
<td>Laura had 23 stuffed animals at home. She gave 8 away to her younger cousin to make room for new toys. How many stuffed animals does she have left?</td>
</tr>
<tr>
<td>Separate Change Unknown</td>
<td>Danny decided to give away some coins from his coin collection. He had 53 coins in his collection. He gave some to his friend Tim. After giving Tim the coins, He had 39 coins remaining. How many coins did he give Tim?</td>
</tr>
<tr>
<td>Separate Start Unknown</td>
<td>Tina is a WNBA fan. She has had many of the players sign autographs for her. At the Phoenix Mercury game on Friday, she got 7 more players to sign their autograph. She now has autographs from 33 WNBA players. How many autographs did she have before the game on Friday?</td>
</tr>
<tr>
<td>Multiplication</td>
<td>Lesley took out 4 bags to put some pieces of Halloween candy. She put 8 pieces of Halloween candy in each bag. How many total pieces of Halloween candy did she have?</td>
</tr>
<tr>
<td>Measurement Division</td>
<td>The librarian is going to display 35 books on 7</td>
</tr>
</tbody>
</table>
shelves. If she places an equal number of books on each shelf, how many books will be displayed on each shelf?

| Partitive Division | The librarian wants to display 35 books. She plans to place 5 books on each shelf. How many shelves does she need to show all her books? |


The importance of illustrating the various problem types here is to see the difference in their degree of difficulty. Students tend to have greater challenges working through change and start unknown problems, both of the join and separate variety. This is consistent with what we see in Tables 5 and 16. The student work samples from the classrooms of both Teacher 2A and Teacher 2B show a high frequency of ratings of 2 and 3 for the *compare* and *multiplication* problem types. The *compare* problem type presented in the classroom of Teacher 2B was similar to that of Teacher 2A and read as follows:

*Student X did 127 sit ups last night. Student Y did 141 sit ups last night. Who did more sit ups; Student X or Student Y?*

When the post problem, which was a *separate change unknown* problem, 6 of the 7 students received ratings of 1 across the four elements of the rubric. It is helpful to illustrate the descriptors for a 1 rating on each element below.

<table>
<thead>
<tr>
<th>Element 1: Extent of work shown.</th>
<th>1 = Some evidence exists of student using mathematical reasoning to arrive at a solution. However, the evidence may be reflective of an unclear understanding of the problem being posed.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element 2: Presence of Mathematical Representations</td>
<td>1 = Minimal evidence exists of student use of mathematical representations to indicate understanding of the problem in context.</td>
</tr>
</tbody>
</table>
Element 3: Persistence
1 = The student made some attempt to solve the problem. Depth of understanding of the question being asked is not evident.

Element 4: Depth of Reasoning
1 = The student demonstrated some evidence of mathematical reasoning in working on the problem although the reasoning may be misaligned to the question being asked.

The frequent ratings of 1 by the students of Teacher 2B on the separate change unknown problem are indicative that students have demonstrated difficulty in comprehending the question being posed in more challenging story problems. This helps triangulate findings of flawed solution strategies observed on video recordings. Teacher 2A also had three instances of students getting ratings of 1 on a separate change unknown problem.

Assertion 5: In some classrooms, traditional, teacher-centered pedagogy was prevalent in instruction.

Teacher-centered pedagogy refers to those instructional strategies that place the teacher at the center of instruction as the expert who is there to impart knowledge to students as passive recipients, similar to Freire’s notion of banking education described in the theoretical framework for this study (Cuban, 1992; Freire, 1971). In the early part of this study, this pedagogical approach predominated in the instruction of Teachers 2A and 2B. For the open code TG VERB, there were 9 instances of this behavior recorded. This code refers to the teacher practice of providing guidance to students by prescribing the strategy that they are to use in problem-solving. In the first instructional round of recordings,
these teachers required the Singapore Math template to be utilized by students as they problem-solved. In a given story problem, they identified who the characters in the story were, what they were doing, created a base-10 drawing representation of the numbers and stated their answer. There were certainly positive results in this practice as students did widely demonstrate an ability to draw base 10 representations of various numbers.

Participating 4th grade teachers also infused teacher-centered pedagogical practices with greater frequency than their participating peers. For example, both Teacher 4A and 4C incorporated more de-contextualized, non-story problems at various points in the video recordings. Teacher 4C spent about half of the second instructional segment on modeling and working with students on order of operations problems. This same teacher also posed three story problems in the third and final instructional recording but announced to the class that they would have to do the first two together before they got to work independently on the third problem.

The influence of our high stakes testing culture was also a clear factor in influencing a reliance on teacher-centered approaches to instruction. Teacher 4A did incorporate story problems into instruction. This teacher also infused a significant amount of de-contextualized math problems that mirrored the format of quarterly benchmark items that students encountered on their quarterly district tests. A sample of some of those problems is shown below to illustrate the influence of testing on teacher pedagogy.
Aaron used a rule to make the number pattern shown below.

\[
\begin{array}{cccccc}
100,000 & 10,000 & 1,000 & 100 & 10
\end{array}
\]

Which of the following uses the same rule?

a. 100,000, 99,000, 98,000, 97,000, 96,000
b. 50, 40, 30, 20, 10
c. 500,000 50,000 5,000 500
d. 5,000 4,000 3,000 2,000 1,000

As can be seen from the format of the above problem, testing plays a great factor in decisions around instruction. Teacher 3C also mentioned how it is important to maintain a balance of traditional and problem-solving based instruction. The consideration of the influence of high stakes testing on instructional decisions is important as it can determine the degree to which students are posed with problem-solving opportunities. The use of classroom space also confirms this assertion as evidence of traditional assignments and warm up problems with few story problems were a part of the classroom environment in several classrooms. Teacher 3C’s classroom for example had several arithmetic problems similar to \(79,386 + 2,578\) among the review skills that students practiced on the whiteboard.

Teachers’ assumptions about how students learn also play a factor in the degree to which students are provided with frequent opportunities to engage in problem-solving. In an interview with Teacher 3B, the teacher shared that ideally students would be provided with CGI instruction daily depending on the skill being taught. It if was a skill that they were already familiar with, then you could engage them in problem-solving around that topic. However, if it was a new skill, the teacher would have to build the students’ knowledge up around the topic as a
pre-requisite to providing the students with frequent problem-solving related to that topic. Interview data further helped triangulate this assertion as teachers made reference to the preoccupation with having to cover so much content. The dilemma of content coverage is directly related to preoccupation with performance on testing. This in turn influences the degree to which teachers will ground their instruction in student-centered strategies like CGI. Teacher responses on their questioning surveys further support this assertion as a question with the lowest amount of agreement was around the following statement on the survey:

_Due to the time consuming nature of higher level questioning in instruction, it should be used only occasionally to allow for greater content coverage._

Participating teachers somewhat agreed with this statement indicating that preoccupations with content coverage for the purpose of testing is a real concern of teachers.

_Assertion 6: CGI as an instructional model has potential benefits for improving student learning._

Improvements in learning are most acknowledged when they manifest in the form of improved student achievement. The quantitative outcomes of this study do not go so far as to claim that improvements in achievement are due entirely to the implementation of CGI as an instructional model. Improvements in student learning also manifest in the formation of habits beyond mere spikes in test scores.
We begin here with quantitative evidence supporting this assertion. In the three archival time series, which were conducted, two of them showed that after the initiation of CGI trainings, cohort performances were better than expected from linear regression. The 3rd and 4th grade students of P.H. Gonzales Elementary School demonstrated achievement outcomes better than what regression would have predicted. This was not the case, however, for the 2nd grade cohort of students. Triangulating these findings was that 2011 3rd graders ceased to have statistically significant declines in achievement compared to 2010 3rd graders who did show a statistically significant decline. Again, we proceed with caution here because 2011 4th graders did decline significantly this fall compared to last year’s 4th grade cohort who did not.

Teacher interviews also uncovered some potential benefits for learning from the CGI model. When asked if they noticed changes in how students approach problem-solving, several teachers noted that they see students being more confident in trying to solve a problem. They also reported benefits of students learning from one another and seeing the different ways that a problem can be solved. Teacher 3B made this point that students were being more confident in making greater efforts to solve story problems.

Assertion 7: Teacher questioning is only as good as the dialogue and learning that it promotes.

This study made great efforts to quantify changes in the level of questioning posed in instruction. It was found that a greater degree of analysis questions were posed over the course of the study; 18 in the first recordings and
26 in the last recordings. However, the mere posing of a higher-level question does not ensure that a student is in fact learning. In video recordings, participating teachers were posing many higher level questions such as what does that number represent, or what is another way that you can solve that? However, a major finding was that students are still by and large demonstrating great misconceptions on understanding various story problems. Several examples were offered in this study of how student work illustrated such misconceptions. A greater number of higher-level questions did not equate to a greater degree of deep level understanding among students around story problems being posed to them.

Limitations

This study had several limitations. One of the main limitations was the duration of the study. Trying to make claims about the achievement benefits of CGI training is problematic when the study has only taken place for a period of 3 months. It would be helpful to continue to track the achievement status of these student cohorts in future semesters to see how changes in instructional styles are impacting their learning.

A second, notable limitation of this study was the process for collecting student work samples to evaluate to answer the second research question. Teachers selected the problems to pose to students for this purpose. As the researcher, it was my belief that this was the best way to go because teachers are the most current on the content that they are teaching at the classroom level. This posed problems for being able to make claims about how students’ approaches to
problem-solving evolved over the duration of the study. In some cases, teachers posed simpler problems on the post samples than the pre-samples making it difficult to evaluate any kind of growth in strategies over the duration of the study.

Another limitation of this study was the relatively low response rates of teachers to the teacher questioning survey. Overall, 5 teachers completed the pre and the post survey. The validity of results would have been strengthened by getting responses from all of the teachers.

Lastly, the professional development was not as explicitly focused on providing teachers with training in questioning methods. Our teachers learned the overarching principles of the CGI philosophy and how to evaluate student work samples to help with instruction. A more explicit emphasis on how to go about engaging students in dialogue through questioning can be beneficial for future research related to an implementation such as CGI.

Implications for Teacher Practice and Policy

Teacher questioning emerged as a limitation in this study in terms of an explicit focus on it during training. As was evidenced from the results, more frequent questions at higher levels of Bloom’s does not automatically guarantee increased quality in student learning experiences. An important implication for teacher practice gleaned from the study is the importance of focusing professional development efforts on the art of questioning to promote genuine dialogue that helps students be reflective on their learning in order to advance it. Ball (1993) walked us through a segment of her considerations for instructional planning as
far as what would be the best way in terms of relatable analogies that would help students conceptualize integers such as money examples or a building with upper floors being positive numbers and lower floors being negative numbers. Such deliberation and reflectiveness in planning is a key skill for maximizing the quality of lessons. While teachers are beginning to pose somewhat more frequent higher order questions, future studies making the planning for such questioning at the one to one level can have important implications for student learning and teacher practice.

Our broader educational context has a great influence on our practice at the classroom level as educators. Policy abounds that ascribes tremendous weight to quantitative outcomes. Quantitative outcomes are important for informing educational practice. Teachers need such information for making instructional decisions and planning for addressing the needs of students. When these outcomes become the basis for rewards and punishment, it has an adverse effect on teacher practice. This was evident in certain points of this study. Teacher interviews, classroom artifacts and lessons revealed that concerns over testing performance often times drive the kind of assignments given, instructional activities in the class and decisions around implementation of different ideas. As it relates to this study, implementation of CGI as the norm for math instruction is making progress but is also subject to this broader context around testing and the idea that content has to be covered so that students are test ready.

Student performance on testing is important as an indicator of how effectively we are teaching and how well our students are learning. In this same
conversation, it is important to remember the deeper purposes for which we are educators. One of the main charges of education today is to prepare the 21st Century Learner for jobs that have yet to be invented. One of the characteristics often ascribed to the 21st Century Learner is the ability to think critically, collaborate and problem-solve. These are important habits that come from frequent opportunities to do each of these. While as educators, it is important for us to keep an eye on achievement outcomes to inform our practice, but it is equally important to facilitate the development of habits of problem-solving in our students for much greater purposes as being able to navigate an ever increasingly, rapid changing world. While technology tools help us in terms of more efficient access to lots of information, the fundamental habits of solving problems creatively and thinking critically about important issues are generalizable to the as of yet unknown issues and challenges that our students will face. While contrived story problems may not mirror grappling with addressing our economic crisis or environmental issues, the frequent open-ended problem-solving opportunities can help internalize in our students’ habits of navigating such problems and being able apply them to more global contexts. Our over-emphasis in testing performance and its ensuing pressures on teachers and students often gets interpreted as a call to cover more content faster, using methods of traditional, rote instruction with which we are already familiar ourselves as students of the 20th Century industrial age. We unconsciously “habituate” our students to conforming to an outdated mold under the perception that we are improving test scores (Dewey, 1916). Dewey (1916) refers to
habituation as the molding of pupils to conform to existing structures, or the status quo versus the formation of habits that allow them to take control over their own environment. In the end, it is important that we keep a balanced perspective on the utility of high stakes testing outcomes as resources for investigation to improve teaching and learning and not crossing the line as making it a hammer for meting out rewards and administering punishments. We owe our students student-centered instruction that takes us as educators outside of our own comfort zones without the fear of reprisals for falling short of quantitative targets. This will require a will to persist in instructional risk taking with our eye on instilling habits of mind that equip students for the end of deep and lifelong learning.
REFERENCES


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Erickson, F. (1986). Qualitative methods in research on teaching. In M. Wittrock, (Ed.) Handbook of research on teaching (3rd ed.).


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APPENDIX A

TEACHER QUESTIONING MATRIX
## Teacher Questioning Matrix

<table>
<thead>
<tr>
<th>Question</th>
<th>Knowledge</th>
<th>Comprehension</th>
<th>Application</th>
<th>Analysis</th>
<th>Evaluation</th>
<th>Synthesis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

*Note: Adapted from Caulfield-Sloan and Ruzicka (2005).*
APPENDIX B

RUBRIC FOR STUDENT PROBLEM-SOLVING
Rubric for Student Problem-Solving

The following rubric is being used for the purpose of evaluating samples of student work on problem-solving scenarios. Four elements related to problem-solving are highlighted: (1) extent of work shown, (2) presence of mathematical representations, (3) persistence, and (4) depth of reasoning. Extent of work shown describes the degree to which students demonstrated the thinking that went into their problem-solving processes on paper. Presence of mathematical reasoning refers to students using pictures, tallies, or other representations to help model the problem that they are solving. Persistence refers to the evidence in their work of putting forth efforts to solve the problem as opposed to just guessing or simply skipping the problem. Finally, depth of reasoning refers to the evidence that can be seen of students explaining or justifying their reasoning in their work. The rubric has ratings ranging from 0 up to 3, with each element having a corresponding descriptor for each rating.

**Element 1: Extent of work shown.**

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No evidence exists of student using mathematical reasoning to arrive at a solution. An answer is either not present or if present, has no accompanying evidence of student thinking.</td>
</tr>
<tr>
<td>1</td>
<td>Some evidence exists of student using mathematical reasoning to arrive at a solution. However, the evidence may be reflective of unclear evidence of understanding the problem being posed.</td>
</tr>
<tr>
<td>2</td>
<td>Adequate evidence of student mathematical reasoning is evidence to justify the solution. The work shown is logically connected to the context of the problem whether the solution is correct or incorrect.</td>
</tr>
<tr>
<td>3</td>
<td>Outstanding evidence of student mathematical reasoning exists in arriving at a solution. Mathematical representations of the problem are present and clearly tied to the context. The reasoning evidence follows a logical and coherent sequence explaining how the student arrived at a correct solution.</td>
</tr>
</tbody>
</table>

Comments:

**Element 2: Presence of Mathematical Representations.**

<table>
<thead>
<tr>
<th>Rating</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No evidence exists of mathematical representations to indicate understanding of the problem in context.</td>
</tr>
<tr>
<td>1</td>
<td>Minimal evidence exists of student use of mathematical representations to indicate understanding of the problem in context.</td>
</tr>
<tr>
<td>2</td>
<td>Student used mathematical representations to indicate a basic understanding of the problem in context. The representation shows a logical connection to the problem being examined.</td>
</tr>
<tr>
<td>3</td>
<td>Student used mathematical representations to illustrate in depth understanding of the problem in context. The representation has a clear and logical connection to the problem being posed.</td>
</tr>
</tbody>
</table>
**Element 3: Persistence**

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>There is no evidence that the student put forth effort to solve the problem. Either no effort was made to solve the problem or guesses were written down with no supporting logic.</td>
</tr>
<tr>
<td>1</td>
<td>The student made some attempt to solve the problem. Depth of understanding of the answer and algorithmic steps is not evident.</td>
</tr>
<tr>
<td>2</td>
<td>There is evidence that the student thoughtfully analyzed what specifically they were being asked to solve. The student selected a solution strategy that may or may not have guided them to an accurate solution.</td>
</tr>
<tr>
<td>3</td>
<td>There is evidence that the student thoughtfully analyzed what specifically they were asked to solve. Furthermore, there was evidence that the student thoughtfully selected solution strategies to accurately solve the problem.</td>
</tr>
</tbody>
</table>

**Element 4: Depth of reasoning.**

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No evidence of mathematical reasoning exists. The student did not attempt the problem or simply wrote an answer with not trail of reasoning.</td>
</tr>
<tr>
<td>1</td>
<td>The student demonstrated some evidence of mathematical reasoning in working on the problem although the reasoning may be misaligned to the question being asked.</td>
</tr>
<tr>
<td>2</td>
<td>The student demonstrates evidence of mathematical reasoning that addresses the question being asked in the problem through a visual representation.</td>
</tr>
<tr>
<td>3</td>
<td>The student demonstrates strong depth of reasoning in the question being asked in the problem. The student provides evidence of explanations as a narrative or through detailed archiving of their problem-solving work.</td>
</tr>
</tbody>
</table>
APPENDIX C

CODEBOOK FOR CLASSROOM VIDEOTAPING
# Classroom Videotaping Codebook

<table>
<thead>
<tr>
<th>Code</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CGI-PED</td>
<td>Refers to pedagogy reflective of CGI principles</td>
</tr>
<tr>
<td>OEQ</td>
<td>Refers to posing of open-ended questions</td>
</tr>
<tr>
<td>SPO</td>
<td>Refers to the degree of story problem opportunities posed in instruction.</td>
</tr>
<tr>
<td>MSS</td>
<td>Refers to opportunities to share multiple solution strategies.</td>
</tr>
<tr>
<td>ST-RSNG</td>
<td>Refers to degree to which teachers have students explain their reasoning.</td>
</tr>
<tr>
<td>STRAT-SH-ARE</td>
<td>Refers to degree to which student have opportunities to share strategies.</td>
</tr>
<tr>
<td>PWP</td>
<td>Refers to whether or not teachers personalize word problems.</td>
</tr>
<tr>
<td>PROB Qs</td>
<td>Degree to which teachers ask probing questions.</td>
</tr>
<tr>
<td>VAL-TH</td>
<td>Degree to which teachers validate student thinking.</td>
</tr>
<tr>
<td>ST-BEH</td>
<td>Problem-solving behaviors in which students engage.</td>
</tr>
<tr>
<td>COL/DIAL</td>
<td>Engagement in collaboration and dialogue with peers.</td>
</tr>
<tr>
<td>ARG</td>
<td>Degree to which students engage in argumentation around solutions.</td>
</tr>
<tr>
<td>CU STRATS</td>
<td>Students’ use of counting up strategies to solve.</td>
</tr>
<tr>
<td>DM STRATS</td>
<td>Students’ use of direct modeling strategies to solve.</td>
</tr>
<tr>
<td>DNF STRAT</td>
<td>Students’ use of derived number facts to solve.</td>
</tr>
<tr>
<td>ALG PRIV</td>
<td>Degree to which students rely on algorithms to solve.</td>
</tr>
<tr>
<td>STMISCON</td>
<td>Degree to which students have misconceptions on story problems.</td>
</tr>
<tr>
<td>UNCLUND</td>
<td>Degree to which students demonstrate unclear understandings of problem.</td>
</tr>
<tr>
<td>TCP</td>
<td>Degree of teacher reliance on teacher-centered pedagogy.</td>
</tr>
<tr>
<td>TG VERB</td>
<td>Degree to which student guide students verbatim on how to solve.</td>
</tr>
<tr>
<td>TD SOL ST</td>
<td>Degree to which solution strategies are driven by teacher.</td>
</tr>
<tr>
<td>PRAISTM</td>
<td>Degree to which teacher praises students for following their method.</td>
</tr>
<tr>
<td>1-WRDRES</td>
<td>Degree to which teacher poses questions eliciting 1 word response.</td>
</tr>
<tr>
<td>MRMQs</td>
<td>Degree to which questions posed only require memorization.</td>
</tr>
<tr>
<td>CGI IMP LEV</td>
<td>The level of implementation observable in math instruction.</td>
</tr>
<tr>
<td>RIG LEV</td>
<td>Level of rigor of problems posed to students in math class.</td>
</tr>
<tr>
<td>Code</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>SP FREQ</td>
<td>The frequency with which story problems are a part of math instruction.</td>
</tr>
<tr>
<td>SP PROP</td>
<td>Proportion of story problems that are decontextualized and drill-style.</td>
</tr>
<tr>
<td>OBST</td>
<td>Obstructions to full CGI Implementation</td>
</tr>
<tr>
<td>MGT/TONE</td>
<td>Classroom management and tone issues.</td>
</tr>
<tr>
<td>PD PERC</td>
<td>Negative perceptions around professional development.</td>
</tr>
<tr>
<td>EXP</td>
<td>Issues of low expectations.</td>
</tr>
<tr>
<td>INFRQNG</td>
<td>Infrequent questioning to check for understanding.</td>
</tr>
<tr>
<td>CL LACK</td>
<td>Lack of clarity in learning.</td>
</tr>
<tr>
<td>PROC/ROUT</td>
<td>Issues with procedures and routines.</td>
</tr>
</tbody>
</table>
APPENDIX D

TEACHER INTERVIEW QUESTIONS
Teacher Interview Questions

1. What are your impressions of the training so far?

2. If you were asked to plan a math professional development, how might it look?

3. How frequently do you think CGI should be a part of classroom instruction?

4. What is your opinion regarding the CGI approach to math instruction?

5. How did you view me in this study as your former principal?

6. Do you think CGI is a worthwhile approach for student to learn math?

7. Have you notice any changes in how students work with math by using CGI?

8. Describe your level of implementation. Why?
Higher Level Questioning Survey

The purpose of this survey is to collect information about the importance that is attached to higher level questioning in instruction and the degree to which it is used in classroom instruction.

Please complete the demographic information below.

1. How many years of teaching experience do you have?
   ___ 0-2 Years  ___ 3-5 Years  ___ 6-8 Years  ___ 9-11 Years  ___ 11+ Years

2. During your teaching career, what grade levels have you primarily taught?
   ___ K-2  ___ 3-5  ___ 6-8  ___ 9-12

The following segment of question relate to the degree of importance attached to higher level questioning in instruction. Please indicate your degree of agreement with each of the following statements.

3. It is important that most questions posed during instruction are at the higher levels of Bloom’s Taxonomy (Application, Analysis, Evaluation, and Synthesis).
   ___ Strongly Agree  ___ Agree  ___ Somewhat Agree  ___ Disagree  ___ Strongly Disagree

4. Asking students frequent higher order questions during instruction prepares them for success on classroom and benchmark assessments.
   ___ Strongly Agree  ___ Agree  ___ Somewhat Agree  ___ Disagree  ___ Strongly Disagree

5. Asking higher level questions frequently during instruction is important for the development of students’ problem-solving abilities.
   ___ Strongly Agree  ___ Agree  ___ Somewhat Agree  ___ Disagree  ___ Strongly Disagree

6. Due to the time consuming nature of higher level questioning in instruction, it should be used occasionally to allow for greater content coverage.
7. Posing frequent higher level questions during instruction is an important strategy to advance our school’s math achievement.

8. I carefully plan for the inclusion of higher level questions in my math instruction.

9. The majority of questions that I pose during math instruction are at the higher levels of Bloom’s Taxonomy (Application, Analysis, Evaluation, & Synthesis).

10. I am reflective of the level of questions that I pose during math instruction.

11. I incorporate higher level questions into my math instruction as a way to prepare students for challenging assessment questions.

12. It is too great of a risk to focus on higher level questions when we are accountable for a great volume of standards to teach.
### Teacher Interview Codebook

<table>
<thead>
<tr>
<th>Codes</th>
<th>Brief Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCHIMP</td>
<td>Teacher impressions of CGI Training</td>
</tr>
<tr>
<td>THNK-AN</td>
<td>Analysis of student thinking</td>
</tr>
<tr>
<td>MSS</td>
<td>Student use of multiple solution strategies</td>
</tr>
<tr>
<td>PD-PRI</td>
<td>Prior professional development of teachers</td>
</tr>
<tr>
<td>RIG-INC</td>
<td>Increasing rigor level of problems</td>
</tr>
<tr>
<td>CCSS</td>
<td>Common Core State Standards</td>
</tr>
<tr>
<td>TR-INF</td>
<td>Reference to training as being informative</td>
</tr>
<tr>
<td>PERSLACK</td>
<td>Lack of persistence on part of students in problem-solving</td>
</tr>
<tr>
<td>STUSTRUG</td>
<td>Students struggling with problem-solving</td>
</tr>
<tr>
<td>CONF-INC</td>
<td>Students’ confidence increasing with problem-solving</td>
</tr>
<tr>
<td>PD-IDEAL</td>
<td>Ideal professional development</td>
</tr>
<tr>
<td>ART-VERT</td>
<td>Vertical articulation</td>
</tr>
<tr>
<td>ASMNTEMPH</td>
<td>Emphasis on student test taking</td>
</tr>
<tr>
<td>MODSUP</td>
<td>Modeling support in professional development</td>
</tr>
<tr>
<td>ADTNLSUP</td>
<td>Additional support for struggling students</td>
</tr>
<tr>
<td>CGI-FREQ</td>
<td>Ideal frequency of CGI approach to instruction</td>
</tr>
<tr>
<td>BASPREREQ</td>
<td>Seeing basic skills as a pre-requisite to problem-solving</td>
</tr>
<tr>
<td>CONT-COV</td>
<td>Focus on coverage of content in instruction</td>
</tr>
<tr>
<td>INCFUTFREQ</td>
<td>Increase frequency of CGI instruction in future</td>
</tr>
<tr>
<td>LES-INTRO</td>
<td>Using CGI as a way to introduce lessons</td>
</tr>
<tr>
<td>CGI-WW</td>
<td>Whether or not CGI is a worthwhile approach to math instruction.</td>
</tr>
<tr>
<td>RR</td>
<td>Researcher’s role in the study</td>
</tr>
<tr>
<td>0-INFL</td>
<td>Researcher has no influence on teacher implementation</td>
</tr>
<tr>
<td>STRAT2IMP</td>
<td>View professional development as strategies to help regardless of researcher</td>
</tr>
<tr>
<td>RESNORTH</td>
<td>Researcher seen as a non-threatening resource</td>
</tr>
<tr>
<td>NEUTOBS</td>
<td>Researcher seen as a neutral observer</td>
</tr>
<tr>
<td>FAM-COM</td>
<td>Familiarity and comfort with researcher</td>
</tr>
<tr>
<td>ST-CHNG</td>
<td>Changes in student work approach with problem-solving</td>
</tr>
<tr>
<td>EVOFUNDST</td>
<td>Evidence of understanding</td>
</tr>
<tr>
<td>Acronym</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>CONF-INC</td>
<td>Increase in student confidence with problem-solving</td>
</tr>
<tr>
<td>IMP-LEV</td>
<td>Level of CGI implementation in instruction</td>
</tr>
<tr>
<td>SCALE-SR</td>
<td>Scale self-rating</td>
</tr>
<tr>
<td>RES-SUP</td>
<td>Need for resource support</td>
</tr>
<tr>
<td>SPGEN</td>
<td>Story problems that generalize across problem types</td>
</tr>
<tr>
<td>MANIPMGT</td>
<td>Management of manipulatives</td>
</tr>
<tr>
<td>TIME CONST</td>
<td>Time constraints</td>
</tr>
</tbody>
</table>
APPENDIX G

IRB PERMISSION MATERIALS
Dear Parent:

I am a graduate student under the direction of Dr. David Lee Carlson, Assistant Professor in the Division of Teacher Preparation at Arizona State University. I am conducting a research study to analyze the impact that a math teaching instructional model, called Cognitively Guided Instruction (CGI) has on the math performance and problem-solving abilities of 2nd through 4th grade students.

I am inviting your child's participation, which will involve analyzing a sample of your child’s work at the beginning of the Fall semester of 2011 on a problem-solving task and a second sample of your child’s work on a problem-solving task at the end of the Fall semester of 2011. The first work sample will be collected in September of 2011 and the second work sample in December of 2011. The duration of this study will be a total of 3.5 months. Your child's participation in this study is voluntary. If you choose not to have your child participate or to withdraw your child from the study at any time, there will be no penalty. A decision not to participate or to withdraw your child from the study will in no way affect your child’s grade or care and attention in their class. The results of the research study may be published, but your child's name will not be used.

Although there may be no direct benefit to your child, the possible benefit of your child's participation includes receiving instruction that is focused on math problem-solving and developing their abilities in working with word problems. There are no foreseeable risks or discomforts to your child’s participation.

Protecting your child’s confidentiality is a priority, and their identity will not be shared at any point in the study. Codes will be assigned to your child’s work samples so that their names are not used or revealed in discussing the results of the study. The study may use a sample of a student’s work to show how their problem-solving work has developed over the course of this study. If you do not want your child’s work to be referenced as a sample, you can indicate below. The results of this study may be used in reports, presentations, or publications but your child’s name will not be used.

If you have any questions concerning the research study or your child's participation in this study, please call me at (623) 533 – 9030 or Dr. David Lee Carlson at (480)-965-4472.

Sincerely,
Juan Medrano

By signing below, you are giving consent for your child __________________

(Child’s name)

to participate in the above study.

_________________________  ________________  _____________
Signature               Printed Name           Date

If you have any questions about you or your child's rights as a subject/participant in this research, or if you feel you or your child have been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the Office of Research Integrity and Assurance, at (480) 965-6788.
EL EFEETO DE INSTRUCCION COGNOSCITIVAMENTE INDICADA EN
ESTUDIANTES PRIMARIOS’ LOGRO de MATEMATICAS, CAPACIDADES de
RESOLUCION DE PROBLEMAS E INTERROGATORIO de MAESTRO

La CARTA PATERNAL DE PERMISO

Estimado Padre / Guardian:

Soy un estudiante de posgrado bajo la dirección de Dr. David Lee Carlson, el
Profesor agregado en la División de Preparación de Maestro en la
Universidad Estatal de Arizona. Realizo un estudio de investigación para
analizar el impacto de un modelo instruccional de enseñanza de
matemáticas, llamada Instrucción Cognoscitivamente Indicada (CGI), tiene en
el desempeño de matemáticas y capacidades de resolución de problemas de
estudiantes entre los grados 2°, 3° y 4°.

Invito la participación de su niño/a, que implicará analizando una muestra
del trabajo de su niño/a al principio del semestre de Otoño de 2011 en una
tarea de resolución de problemas y una segunda muestra del trabajo de su
niño en una tarea de resolución de problemas a fines del semestre de Otoño
de 2011. La primera muestra del trabajo será colectada en septiembre de
2011 y la segunda muestra de trabajo en diciembre de 2011. La duración de
este estudio será un suma de 3.5 meses. La participación de su niño/a en este
estudio es voluntaria. Si escoge no tener a su niño/a participar o para retirar
a su niño/a del estudio en tiempo, no habrá pena. Una decisión de no
participar o retirar a su niño/a del estudio no afecta de ninguna manera el
grado de su niño/a o el cuidado y la atención en su clase. Los resultados del
estudio de investigación pueden ser publicados, pero el nombre de su niño
no será utilizado.

Aunque no es posible que haya beneficio directo a su niño/a, el beneficio
posible de la participación de su niño/a incluye recibiendo instrucción que es
centrada en resolución de problemas de matemáticas y desarrollar sus
capacidades a trabajar con problemas de palabras. No hay riesgos ni
molestias previsibles a la participación de su niño.

Proteger la confidencialidad de su niño/a es una prioridad, y su identidad no
será compartida en ningún punto en el estudio. Los códigos serán asignados
da muestras del trabajo de su niño para que sus nombres no sean utilizados ni
son revelados a discutir los resultados del estudio. El estudio puede utilizar
una muestra del trabajo de un estudiante para mostrar cómo su trabajo de
resolución de problemas ha desarrollado sobre el curso de este estudio. Si
usted no desea que el trabajo de su niño/a sea mencionado como una
muestra, puede indicar abajo. Los resultados de este estudio pueden ser
utilizados en reportes, en las presentaciones, o en las publicaciones pero el nombre de su niño/a no será utilizado.

Si tiene cualquier pregunta con respecto al estudio de investigación o la participación de su niño/a en este estudio, por favor me llame al (623) 533 – 9030 o el Dr. David Lee Carlson en (480)-965-4472.

Sinceramente,

Juan Medrano

Firmando abajo, da consentimiento para su niño/a ____________________________

(el nombre de Niño)

tomar parte en el estudio antes mencionado.

La Firma ________________  Imprimió de Nombre: ____________________________

Fecha: ____________________________

Si tiene cualquier pregunta acerca de usted o los derechos de su niño/a como un sujeto/participante en esta investigación, o si usted se siente que usted o su niño/a han sido colocado en riesgo, puede contactar la Silla de los Sujetos Humanos la Tabla Institucional de Revisión, por la Oficina de Integridad de Investigación y Certeza, en (480) 965-6788.
Dear Parent:

I am a graduate student under the direction of Dr. David Lee Carlson, Assistant Professor in the College of Teacher Preparation at Arizona State University. I am conducting a research study to analyze the impact that a math teaching instructional model, called Cognitively Guided Instruction (CGI) has on the math performance and problem-solving abilities of 2nd through 4th grade students.

I am inviting your child's participation, which will involve videotaping their classroom during instruction while they work on math problem-solving tasks. The purpose will be to see how their problem-solving approaches change over the duration of the study. Their interaction during classroom instruction will be videotaped three times during the Fall semester of 2011; once in August, a second time in November and a final time in December. All videotapes will be stored at Arizona State University to ensure the confidentiality of your child. The duration of this study will be a total of 3.5 months. Your child's participation in this study is voluntary. If you choose not to have your child participate or to withdraw your child from the study at any time, there will be no penalty. A decision not to participate or to withdraw your child from the study will in no way affect your child’s grade or care and attention in their class. The results of the research study may be published, but your child's name will not be used.

Although there may be no direct benefit to your child, the possible benefit of your child's participation includes receiving instruction that is focused on math problem-solving and developing their abilities in working with word problems. There are no foreseeable risks or discomforts to your child's participation.

Protecting your child’s confidentiality is a priority, and their identity will not be shared at any point in the study. Your child’s discussions as they work on problem-solving tasks will be kept confidential. The study may use segments of your child’s discussions as they work on problems with peers and their teacher, but their names or identities will not be revealed. All students will have a code assigned in place of their name to further ensure their confidentiality. This code will be referred to in the study as opposed to your child’s name. If you do not want your child’s discussions to be referenced as a sample, you can indicate below. The results of this study may be used in reports, presentations, or publications but your child’s name will not be used.
If you have any questions concerning the research study or your child's participation in this study, please call me at (623) 533–9030 or Dr. David Lee Carlson at (480)965-4472.

Sincerely,

Juan Medrano

By signing below, you are giving consent for your child ______________________

(Child’s name)

to participate in the above study which includes videotaping them as they work on problem-solving tasks.

__________________________  ____________________________  ________________
Signature                  Printed Name                  Date

If you have any questions about you or your child's rights as a subject/participant in this research, or if you feel you or your child has been placed at risk, you can contact the Chair of the Human Subjects Institutional Review Board, through the Office of Research Integrity and Assurance, at (480) 965-6788.
EL EFECTO DE INSTRUCCION COGNOSCITIVAMENTE INDICADA EN
ESTUDIANTES PRIMARIOS’ LOGRO de MATEMATICAS, CAPACIDADES de
RESOLUCION DE PROBLEMAS E INTERROGATORIO de MAESTRO

La CARTA PATERNAL DE PERMISO: CINTA DE VIDEO

Estimado Padre:

Soy un estudiante de posgrado bajo la dirección de Dr. David Lee Carlson, el
Profesor agregado en el Colegio de Maestro Preparación en la Universidad
Estatal de Arizona. Realizo un estudio de investigación para analizar el
impacto de un modelo instruccional de enseñanza de matemáticas, llamada
Instrucción Cognoscitivamente Indicada (CGI), tiene en el desempeño de
matemáticas y capacidades de resolución de problemas para estudiantes
entre los grados 2°, 3° y 4°.

Invito la participación de su niño/a, que implicará grabando en vídeo su aula
durante instrucción mientras trabajan en tareas de resolución de problemas
de matemáticas. El propósito será de ver cómo sus estrategias de trabajar en
la resolución de problemas cambian sobre la duración del estudio. Su
interacción durante instrucción de aula será grabada en vídeo tres veces
durante el semestre de Otoño de 2011; una vez en agosto, un segundo tiempo
en noviembre y un tiempo final en diciembre. Todas las cintas de vídeo serán
almacenadas guardada en la Universidad Estatal de Arizona para asegurar la
confidencialidad de su niño/a. La duración de este estudio será un suma de
3.5 meses. La participación de su niño/a en este estudio es voluntaria. Si
escoge no tener a su niño/a participar o para retirar a su niño/a del estudio
en tiempo, no habrá pena. Una decisión de no participar o retirar a su niño/a
del estudio no afecta de ninguna manera el grado de su niño/a o el cuidado
y la atención en su clase. Los resultados del estudio de investigación pueden
ser publicados, pero el nombre de su niño/a no será utilizado.

Aunque no es posible que haya beneficio directo a su niño/a, el beneficio
posible de la participación de su niño/a incluye recibiendo instrucción que es
centrada en resolución de problemas de matemáticas y desarrollar sus
capacidades a trabajar con problemas de palabras. No hay riesgos ni
molestias previsibles a la participación de su niño.

Proteger la confidencialidad de su niño/a es una prioridad, y su identidad no
será compartida en ningún punto en el estudio. Las discusiones de su niño/a
como trabajan en tareas de resolución de problemas será mantenido
confidencial. El estudio puede utilizar segmentos de las discusiones de su
niño/a como trabajan en problemas con iguales y su maestro, pero sus
nombres o las identidades no serán revelados. Todos los estudiantes tendrán
un código asignado en lugar de su nombre para asegurar aún más su
confidencialidad. Este código será referido a en el estudio en comparación con el nombre

de su niño/a. Si usted no desea que las discusiones de su niño/a sean mencionadas como una muestra, puede indicar abajo. Los resultados de este estudio pueden ser utilizados en reportes, en las presentaciones, o en las publicaciones pero el nombre de su niño/a no serán utilizados.

Si tiene cualquier pregunta con respecto al estudio de investigación o la participación de su niño/a en este estudio, por favor me llame al (623) 533 – 9030 o el Dr. David Lee Carlson en (480) 965-4472.

Sinceramente,

Juan Medrano

Firmando abajo, da consentimiento para su niño/a ____________________________
(el nombre de Niño)

tomar parte en el estudio antes mencionado que incluye los grabar en video como trabajan en tareas de resolución de problemas.

La Firma _____________ Imprimió de Nombre: _______________________

Fecha: _____________________

Si tiene cualquier pregunta acerca de usted o los derechos de su niño/a como un sujeto/participante en esta investigación, o si usted se siente que usted o su niño/a ha sido colocado en riesgo, puede contactar la Silla de los Sujetos Humanos la Tabla Institucional de Revisión, por la Oficina de Integridad de Investigación y Certeza, en (480) 965-6788.
Dear Teacher,

My name is Juan Medrano, and I am the Science, Technology, Engineering, and Math (S.T.E.M.) Director in the Tolleson Elementary School District. I am conducting research on a math instructional model called Cognitively Guided Instruction (CGI) that is intended to improve our teaching of problem-solving to our kindergarten through 4th grade students. I am conducting this research as a student-researcher in my doctoral studies program at ASU West. As this research is conducted, I ask your permission to videotape 10 to 15 minutes of your instruction at the beginning of the Fall semester of 2011 and once more at the end of the 2011 Fall semester.

I am collecting this data solely as a student-researcher. I will analyze this data and focus on the nature of questioning that is posed during instruction and how this engages students in their problem-solving process. Your participation is entirely optional, and the data collected is strictly for research purposes. Your identity will not be revealed at any point in this research study. Thank you for your consideration and assistance in conducting this research.

Sincerely,

Juan Medrano
Student-Researcher
ASU West

_______ Yes, I grant permission for you to videotape my instruction.

_______ No, I do not grant permission for you to videotape my instruction.

Teacher Name (Printed): ________________________________

Teacher Signature: __________________ Date: ____________