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The Relationship Between the Use of Curriculum Materials and Inquiry-Based Pedagogy

Laura Jo Elzinga
Brigham Young University

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Laura Jo Elzinga

A thesis submitted to the faculty of
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Master of Arts

Damon L. Bahr, Chair
Bryant Jensen
Alessandro Rosborough
Sterling C. Hilton

Department of Teacher Education

Brigham Young University

ABSTRACT

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Laura Jo Elzinga
Department of Teacher Education, BYU
Master of Arts

Little change has resulted from decades of attempts at reforming the teaching of mathematics (Davis et al., 1990). This study involved approximately 43 teachers who had completed an inquiry-based professional development program prior to being provided with a new mathematics curriculum designed to support inquiry-based teaching. It analyzed the relationships between their implementation of the inquiry-based teaching and their use of the curriculum materials. A series of bivariate correlations were run to investigate the relationships between the professional development and aspects related to the implementation of the new curriculum. The factors being so inter-related, it was hypothesized that relationships would exist between all of the factors, but only some of the expected relationships materialized. Like others before, this study supports the idea that merely providing professional development and new curriculum will not always result in a change in teaching. While the teachers in this study were not necessarily resistant to change, a lack of time to implement new teaching does seem to have affected the level of change in teaching. Future research is needed related to methods and timing related to the implementation of new teaching practices and curriculum and their relationship to teacher change.

Keywords: mathematics, inquiry-based teaching, curriculum

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CHAPTER 1

Introduction

In this study, I seek to examine the relationships between a group of teachers' use of a mathematics curriculum and their instructional practice based on a teaching framework: both related to the same perspective arising from the current reform in mathematics education. This chapter will begin with a general summary of reform-based mathematics education and an argument for teachers' need of a framework that more explicitly defines mathematics-teaching practice. In order to specifically characterize what the teaching looks like, I will describe the framework as well as a basic review of the professional development system that was designed to help teachers improve their practice by learning about the framework. I will also discuss the necessity of having a curriculum to complement teaching practice and then outline a specific curriculum that matches the framework.

Statement of the Problem

Since 1980, the National Council of Teachers of Mathematics (NCTM) has provided a consistent vision of high quality mathematics teaching and learning (NCTM, 1980; NCTM, 1989; NCTM, 2000; NCTM, 2014) that characterizes the current reform movement in mathematics education and includes a list of principles that characterize classroom practice:

- establish mathematics goals to focus learning
- implement tasks that promote reasoning and problem solving
- use and connect mathematical representations
- facilitate meaningful mathematical discourse
- pose purposeful questions
- build procedural fluency from conceptual understanding

- support productive struggle in learning mathematics
- elicit and use evidence of student thinking (NCTM, 2014)

Teaching mathematics well is complex and multi-dimensional and this list of principles represents a dramatic change from traditional modes of mathematics instruction that include defining mathematics as a set of rules and procedures for students to memorize, teaching as telling and the transmission of information, and learning as a process of rote practice.

Much is known about what support teachers need to help them make the change to reform-based mathematics teaching. Indeed, large shifts or changes in student and teacher roles are more likely to occur if teachers are appropriately supported (Chazan & Ball, 1999). Such support includes providing a framework with specific teaching strategies and curriculum materials to support the implementation of that framework (Firestone et al., 2004).

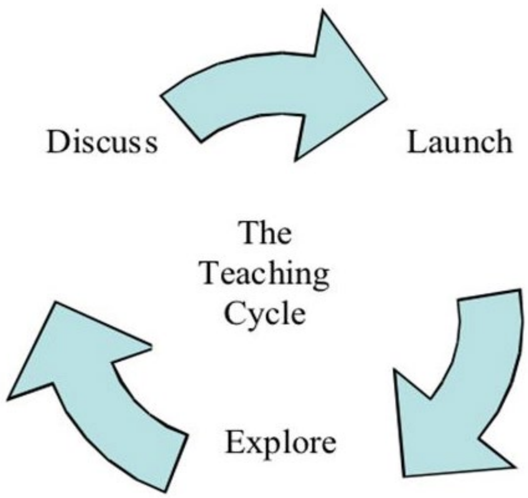
The Comprehensive Mathematics Framework

Although the NCTM states that the above principles provide a framework to guide change in teacher practice, the list itself is more a set of principles than an actual instructional framework or planning model. A teaching framework can guide a teacher's planning, instruction, and professional practices in the classroom. Chazan and Ball (1999) argue that educators are often left "with no framework for the kinds of specific, constructive pedagogical moves that teachers might make" (p. 2). It would appear to be a case of teachers being told what to do without being given the guidance and resources to accomplish the task. The teaching framework shared with the teachers in this study was specifically designed to align with the reform-based principles described above. In the early 2000s, the Brigham Young University-Public School Partnership worked collaboratively to develop and implement a common framework for literacy instruction that was so successful the governing board of the Partnership, consisting of five local superintendents and the school of education dean, created a committee of university and public school personnel charged with developing a framework for teaching mathematics. Designed to guide teachers' implementation of inquiry-based instruction in mathematics classes, the Comprehensive Mathematics Instruction (CMI) Framework employs the reform-based principles of the NCTM. The CMI Framework acknowledges the socially interactive nature of teaching and consists of three components: *Teaching Cycle*, the *Learning Cycle*, and the *Continuum of Mathematical Understanding*.

The *Teaching Cycle* is based on the original work of Shroyer and Fitzgerald (1986) and supports inquiry-based teaching as the teacher moves through the three stages (Figure 1). First is the *launch* where the teacher engages the students in a mathematical task without telling them how to solve it. The students move into *explore* as they are allowed to struggle with the problem at hand. During this time, the teacher circulates the room, prompting or guiding student exploration as necessary. While observing student thinking, the teacher will select those ideas or strategies that will be shared in the third stage of the lesson, *discuss*. During this final stage, students share their strategies in a teacher-led class discussion.

Figure 1

The Teaching Cycle



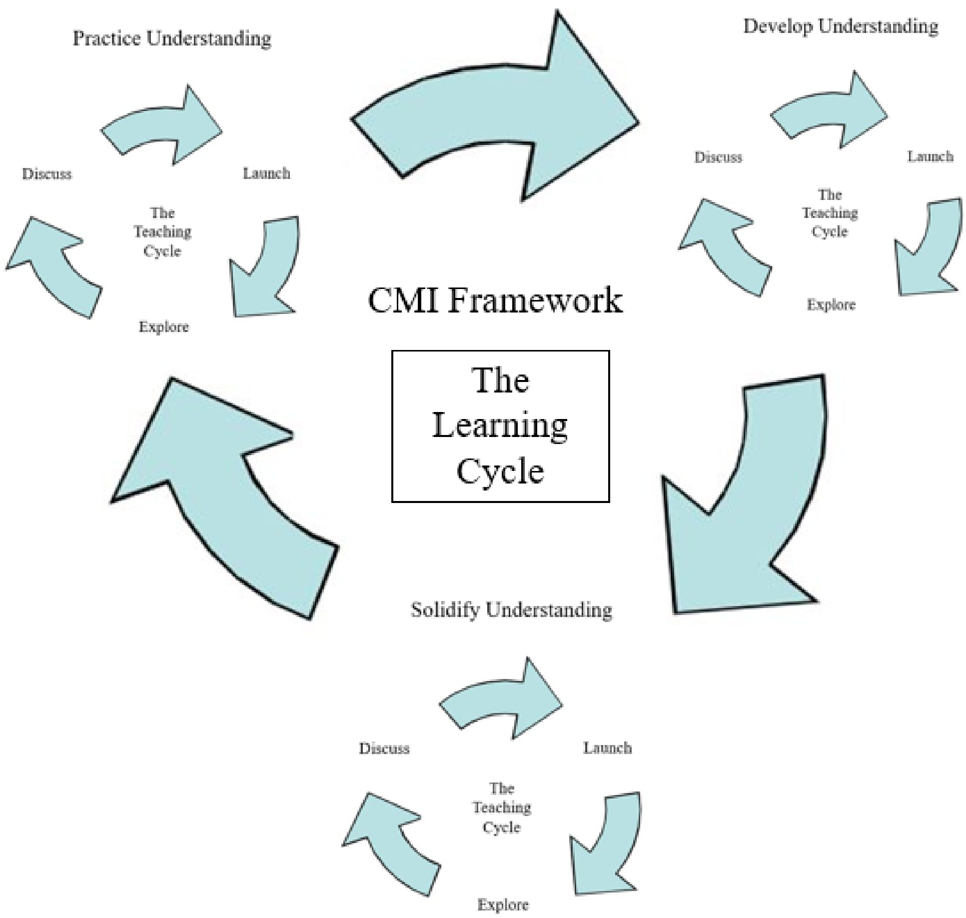
Note. From "The comprehensive mathematics instruction (CMI) framework: A new lens for examining teaching and learning in the mathematics classroom," by S. Hendrickson, S. C. Hilton, & D. Bahr, 2010, *Impact, 11*(2), 21-26. Reprinted with permission.

The *Learning Cycle* is unique to the CMI Framework and suggests how understanding develops as student thinking moves through three phases. It begins with the *develop understanding* phase. This phase is designed to introduce students to the mathematics being developed and surface their understandings and misunderstandings. The second phase, *solidify understanding*, asks students to examine and extend the thinking that was surfaced in the develop understanding phase so they can begin to solidify correct thinking. *Practice understanding*, the final phase, gives students the opportunity to develop fluency with the understanding they have acquired. It is important to note that the phases are not a checklist to be run through with automatic advancement. Rather, a teacher is expected to assess the students at the end of each phase to determine if they are ready to move on or if the class should continue with additional tasks in the same phase.

Teachers use the *Teaching* and *Learning Cycles* interactively when designing and implementing instruction. As depicted in Figure 2, each phase of the *Learning Cycle* contains a complete *Teaching Cycle*, suggesting that the student and teacher roles in the *Teaching Cycle* change as student understanding progresses through the phases of the *Learning Cycle*.

Figure 2

The Learning Cycle



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The instruction provided to students whose understanding is in the develop phase is designed to surface student thinking regarding a new mathematical topic. During the launch, the teacher introduces a task with multiple solutions or in which multiple methods can be used to arrive at the solution. As the teacher introduces and clarifies the task, student background knowledge is activated, allowing students to begin making connections with prior learning. After the students have had time to ask questions about the task, they move into the explore stage where they have the opportunity to engage in the task. The purpose of this stage is to allow students to develop multiple problem solving ideas, strategies, and representations. This is a time for students to reflect, question, and explain their thinking. They might ask themselves "Does this make sense?" or "Have I seen this before?" and use their background knowledge to explain their thinking. The teacher formatively assesses the students' work and selects the thinking to be shared in the discuss stage. In the discuss stage, the students share and compare their thinking with the class. It is an opportunity for them to see alternative approaches to solving the task and the reasoning behind those approaches, and to make connections to their own thinking. The discuss stage is also when the teacher determines if the students are ready to move on to the next phase or if they need to spend more time developing their understanding.

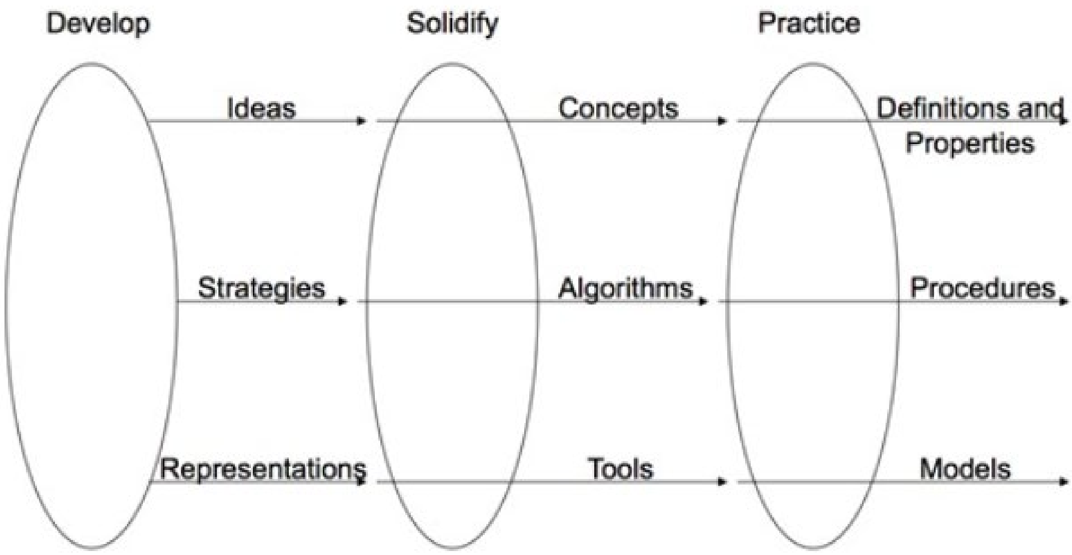
The second phase is solidify understanding and its purpose is to give students the opportunity to examine and extend their thinking, leading to the construction of concepts, algorithms, and tools. The launch in this stage begins with a string of related problems or tasks designed to connect, confirm, and generalize mathematical understanding, giving students the opportunity to reflect on their experiences in the previous phase. During the explore, the teacher directs student understanding by asking questions that probe, clarify, scaffold, and connect. Students will use their background knowledge and reflect, question, explain, and justify. This is also a time for students to focus on one or two strategies as they overcome their misconceptions and begin to make the mathematics that was implicit in their explanations during the previous phase more explicit and identifiable. The discuss stage in the solidify phase is different from discuss in the previous phase. Students are asked to explain and justify their knowledge, using the correct mathematical vocabulary and symbols. At the end of discuss, the teacher determines the next phase of the learning cycle: repeat solidify understanding, return to develop understanding, or move on to practice understanding.

The practice understanding phase is designed to allow students to refine and become fluent with the concepts, algorithms, and tools constructed in the first two phases. The teacher's role is to provide a vehicle for practice and individualized feedback. This may be in the form of a task as in the first two phases or a game or worksheet, depending on the students' level of fluency. While working in this phase, the students reflect and ask such questions as "Is this accurate?" or "Where would I use this?" Students are encouraged to question their own accuracy and justify their work. It is during this phase that students should begin to reason quantitatively and work towards efficiency, flexibility, and automaticity. As with the previous two phases, the teacher determines if the students need to remain in practice understanding, return to solidify understanding, or if they are ready to move on to a new topic.

The third component of the CMI Framework is the *Continuum of Mathematical Understanding* (Figure 3). Mathematical understanding progresses through three connected but specific domains; conceptualizing mathematics, doing mathematics, and representing mathematics. The horizontal lines in the *Continuum of Mathematical Understanding* represent these. As students move through each of the three phases of the *Learning Cycle,* they progress through the distinct domains of the continuum.

Figure 3

The Continuum of Mathematical Understanding



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Movement along the *Continuum of Mathematical Understanding* occurs through connections between the domains and corresponds with the progression through the *Learning Cycle.* As students move through their initial tasks of the develop understanding phase, the images first surfaced are fragile. On the continuum, these images are referred to as ideas, strategies, and representations. When students move through the continuum (and into solidify understanding), multiple exposures and experiences with these ideas, strategies, and representations allow students to examine them for accuracy and completeness, extend, and connect until they become more distinct, solid, and useful. Ideas become concepts, strategies become algorithms, and representations become tools. Although understanding has been developed and solidified, it is not yet fluent. As students refine and practice, concepts become definitions or properties, algorithms become procedures, and tools become models (practice understanding). When the goals of refinement and fluency have been attained the definitions and properties, procedures, and models will be consistent with those of the mathematics community.

Comprehensive Mathematics Framework: Professional Development

Teachers require multiple opportunities and resources to continue increasing their own mathematical understanding and teaching skills (NCTM, 2000). When the CMI Framework was complete, the developers realized that there was not an existing professional development that fit the framework very well. Therefore, the *CMI Professional Development System* was created to provide teachers with information about using the CMI Framework. It supports teachers in their understanding of inquiry-based teaching and helps them strengthen their ability to teach for deep mathematical understanding. The corresponding *CMI Professional Development System* development helps teachers "bridge the gap between the good pedagogical strategies of traditional instruction and the recommendations of reform-based instruction" (Hendrickson et al., 2010).

Investigations in Number, Data, and Space

In addition to a framework, teachers also need reform-based curriculum materials to support their transition to inquiry-based teaching. The CMI Framework is not a curriculum, it is a framework designed to help classroom teachers with their instructional practices and deepen students' mathematical understanding. Using the textbooks and curriculum materials provided by their districts along with the CMI Framework, teachers are better able to plan and design lessons, anticipate student thinking, and facilitate classroom discussions that allow students to continually explore mathematical ideas that lead to mathematical understanding.

Investigations in Number, Data, and Space (*Investigations*) is a K-5 mathematics curriculum published by Pearson Scott Foresman and was designed to engage students in making sense of mathematics. Embedded in the curriculum are the eight mathematical practices for students, from the *Common Core State Standards for Mathematics*:

- make sense of problems and persevere in solving them
- reason abstractly and quantitatively
- construct viable arguments and critique the reasoning of others
- model with mathematics
- use appropriate tools strategically
- attend to precision
- look for and make use of structure
- look for and express regularity in repeated reasoning (NCTM 2014)

The curriculum is task-based and students are encouraged to develop their own, multiple methods for solving problems. Although the CMI Framework was not used to guide the development of the *Investigations* curriculum, it is quite prominent within it. Each lesson consists of one or more launches, i.e., tasks of various types that reflect a clear connection with the *Common Core*. The mathematics associated with the task, along with the student thinking it is designed to surface, are made explicit for the teacher. *Investigations* was created with the thought that students can construct their own mathematical understanding and should be invited to build on these ideas and apply what they know to new situations, to think and to reason.

Statement of Purpose and Research Questions

A group of teachers in one of the BYU-Public School Partnership districts was provided with a reform-based teaching framework, the corresponding professional development, and a curriculum designed to support reform-based teaching (*Investigations*). The purpose of this study was to investigate the relationships between the implementation of the framework and the curriculum. I investigated the following questions:

1. To what extent are teachers' understanding, perceived usefulness, and frequency of use of *Investigations* related to each other?
2. To what extent are these views of *Investigations* related to the self-reported implementation (how well and how often) of the CMI Framework?

As this group of teachers had received extensive professional development on a reform-based teaching framework and then had been given reform-based curriculum, it led to the following hypotheses:

1. There will be strong, positive, and statistically significant relationships among the factors related to the use of the curriculum materials.
2. There will be a strong, positive, and statistically significant relationships between the factors related to the quality and frequency of CMI implementation, and among those factors and the factors related to the use of curriculum materials.

CHAPTER 2

Review of Literature

With the launch of Sputnik in 1957 came a fear in the United States that students were not performing in school well enough to keep up with the rest of the world, especially in science and mathematics. As a response to these concerns came a wide variety of modifications to mathematics instruction in the 1950s and 60s. Often lumped together and called "New Math," these methods were not only vastly different from the traditional modes of instruction, they varied significantly amongst themselves. These two factors, combined with a lack of adequate data regarding its effectiveness, prevented widespread or long-lasting changes to mathematics instruction. Eventually, the fervor died down and mathematics instruction continued on much as before (Davis et al., 1990).

By the mid-1980s, test scores in the United States were at an all-time low. *A Nation at Risk*, released in 1983, was particularly influential in reviving previous concerns about the level of student performance and in promoting educational reform. However, a change had occurred in education since the previous attempts at reform in the 1950s and 1960s. In the 1970s, the work of Lev Vygotsky around sociocultural theory began to attract attention and interest in the field of education. His work began to alter the thinking around how children learn, grow, and develop.

Sociocultural Theory

As far back as Socrates, the idea of a social aspect to learning has existed. Vygotsky (1986) presents language as a mediational tool used for not only communicating with others but as a way to organize our thoughts and to reason and plan. He brought forth the idea that learning precedes development – the exact opposite of what had been thought previously. Instead, he suggested that a complex multi-directional relationship exists between learners, their environment, culture, and past experiences (history), and that the psychological, physical, or symbolic tools (e.g., created by humans or history) used in the same environment for each child will not bring about the same result (Daniels et al., 2007). The new idea grew that children can think, discover, and construct knowledge (e.g. mathematical) without having to be told in one top-down direction from the teacher. It is possible for students to actively construct their own mathematical knowledge relative to their existing knowledge and history if they use these tools in a mediational way that promotes forward thinking and deeper learning that leads to development. In other words, all new knowledge is affected by previous experience as students seek to make sense of their environments. As students learn, they adapt or modify their existing internal knowledge in relation to the application of the tools they use. Learning is not about simply mimicry, but about imitation, working in somewhat similar fashions, with the difference being that imitation accounts for identity and background knowledge of the learner coming forward (i.e., Zone of Proximal Development [ZPD]; Chaiklin, 2003). The freedom to do their own thinking creates an unrestrictive environment where children can improvise their own understanding, each according to their own experiences and cultural history. The various ways of teaching are what will allow the background knowledge to come out. Students need to become more conscious of what they are doing through the math. This use allows teachers to see what the child knows and what the child needs.

Vygotsky (1986) did not believe it possible to separate learning from the use of mediational means, including social context. Further, he believed that understandings or meaning making can emerge from social interaction, which is often manifested through discussion and interacting with others through language. Specific to constructing mathematical understanding, teachers need to create an environment where students can use language as a mediational tool to take on the challenge of increasing/deepening their own understanding. The interaction and collaboration between two or more people can be viewed as a mediational tool that has the potential to not only help students learn, but to lead them into development. New knowledge is not like additional building blocks merely stacked on top of blocks previously placed, but all of the blocks are continuously reorganized as new ones are acquired (Doolittle, 2014). In contrast to earlier classrooms, where the teacher was all-powerful and held all knowledge, Vygotsky speaks of more knowledgeable others (MKOs) who can be students as well as teachers. The MKO cooperates with the learner, allowing them to take the lead (imitation) with whichever tool is being used in order to demonstrate their understanding. The more opportunities students have to take the lead in the collaborative conversation, the greater the chances for understanding. As the teacher provides more opportunities for collaborative conversation, each student is more likely to have the chance to be a learner, or at times the MKO depending on their strengths or what the conversational moment proposes. In such a ZPD-like scenario, learning can take place for both MKOs and learners. In this case, learners increase their understanding as they explain their thinking to the MKO and the MKO can increase their understanding as the MKO allows the learner to take the lead and possibly share concepts or ideas that the MKO may not have previously considered. High levels of interaction in a classroom can allow the MKO role to be shared among students based on the students' prior knowledge and then such shared knowledge can be used as a means to improve understanding. The call to focus more on language in learning and the renewed call for change led to a variety of responses in support of mathematics education reform (Davis et al., 1990). However, it may be that in focusing on more language, MKOs, and interaction in math, there may still be questions about deeper learning coming from these interactions. In Vygotskian Sociocultural Theory (SCT), the model and interactions should be open enough to empower teachers to act and make informed decisions in how to work with students. Agentive teaching includes being able to change with the students' differing answers and empowers both the teacher and learners to be able to make new changes according to the contingencies of the moment (van Lier, 1996). Although Vygotsky's viewpoint was not used directly, his perspective is clearly visible in many of the goals established for mathematical instruction in recent decades.

Mathematics Education Goals

In 1989, in the *Curriculum and Evaluation Standards for School Mathematics*, the National Council of Teachers of Mathematics (NCTM) outlined five new learning goals for mathematics students that reflect the changes in the ideas related to how children learn and understand mathematics:

- learning to value mathematics - understanding the historical impact on current technology
- becoming confident - recognizing the universal nature of mathematics
- problem solving - solving a diverse scope of problems independently and cooperatively
- communicating mathematically - fluency in both written and oral communication
- reason mathematically - supporting a mathematical argument (NCTM 1989)

The new goals are set to allow students to acquire an understanding of mathematical concepts, not merely a rote memorization of rules, steps and procedures (NCTM, 1989). Implicit in these goals is the idea that students will no longer be told, "Here is the one right way to do math" but instead will be encouraged to spend time exploring math, even guessing and making and correcting mistakes. Exploration exposes them to a variety of mathematical experiences and as students begin to construct their own meanings, mathematics becomes a natural language for them as they become mathematically literate (NCTM, 1989).

The goals are a reflection of the true nature of mathematics rather than an explication of social constructivism. However, constructivism can provide a perspective for teachers who endeavor to achieve these goals. As mathematics teachers continue to strive towards the goals set by the NCTM, this second attempt at mathematics education reform is faring better than previous attempts. With that said, it is still questionable whether constructivism alone will provide the answers of more engagement, more agency, and deeper teaching/learning experiences for the teachers and students. Adjusting to the changing roles for both teachers and students is a prolonged undertaking that will require teachers to exercise patience and acquire new knowledge (Fraivillig et al., 1999).

Reform-Based Shift in Roles

New goals in mathematics education have given students a new role more consistent with a constructivist perspective. Students are now expected to take a more active part in learning mathematics rather than the passive role that has been theirs in the past (NCTM, 1989). Comparable to the NCTM goals to some extent, the *Curriculum and Evaluation Standards* (NCTM, 1989), as well as its successor document, the *Principles and Standards* (NCTM, 2000) document five process standards that help define the new student role, problem solving, communication, reasoning and proof, connections, and representation. When solving problems, students are able to extend and solidify what they already know and use this knowledge to explore new concepts allowing them to gain new mathematical understanding. The communication or sharing of ideas allows students to clarify their understanding through conversations in which mathematical ideas are explored. Students use reasoning and proof to develop previously generated ideas, explore new ideas, and justify the results of their thinking. Making connections creates a deeper and longer lasting understanding of previous mathematical experiences. Representation used as a mediational tool can help support students' mathematical understanding and assists in their communicating and connections.

The new mathematics goals also create a change in the teacher role accompanied by a significant change in teachers' practice. Some of the changes include facilitating more active student involvement, allowing for the use of concrete materials such as manipulatives and calculators, creating opportunities for group work, student writing and journaling, and the use of real world contexts (Herrera & Owens, 2001). The new teacher role involves facilitating the investigation of mathematical concepts and assessment of student learning that is no longer separate from, but is a part of, teaching (Dowling, 1995). However, it is important to note that reform-based mathematics instruction is not a free-for-all where the teacher stands aside as students have a playtime with the manipulatives, e.g., "show and tell" (Ball, 2001; Stein et al., 2008). Instead, Cobb et al. (1992) have defined mathematics as a social practice consisting of activities carefully chosen and managed by the teacher.

The new goals have increased the focus on students with the teacher becoming the facilitator who carefully orchestrates the classroom discussion (Williams & Baxter, 1996). The role of the teacher, though different, is still essential. Teachers need to foster a social climate in the classroom that allows all students the opportunity to discuss and reveal their mathematical thinking (Clements & Battista, 1990). While Vygotsky's (1986) more knowledgeable other might not necessarily need to be a teacher, research has shown that not all MKOs are created equally. In reform-based mathematics instruction, the dialogue is what contributes to the development of the conceptual understandings; and for Vygotsky, this would mean anything that is tool mediated with goal directed actions. As the director of the dialogue, Bozkurt (2017) describes as "pivotal" the role of teachers when it comes to helping students learn to communicate mathematically through scaffolding and assisting with the use of mathematical language. It is important to note here that with this type of scaffolding it is not necessarily ZPD or learning that leads to development but instead has the potential to create some mediational means for learning. While the new goals give a focus for teachers to consider, that alone is not enough to bring about changes in teacher and student roles. Also needed is the access to the many materials that strongly support inquiry-based instruction. It is unlikely that a teacher will be able to make the change to reform-based teaching without access to the professional development and curriculum materials necessary to support such teaching (Firestone et al., 2004).

Curriculum

There may have been a time when reform-based teaching shunned the use of curriculum materials, but with the increase in professional development and standards-based curriculum available, Drake et al. (2014) contend that there needs to be a shift in the understanding of the use of curriculum materials to one that implies that "good elementary mathematics teachers are those who use educative curriculum materials well" (p. 154). Curriculum materials can influence what is taught and how it is taught in the classroom (Briars, 2014; Firestone et al., 2004). They help teachers fulfill the principles of the *Common Core State Standards* and provide a research-based scope and sequence to direct what mathematics should be learned and when (Collopy, 2003). Curriculum materials supply worthwhile mathematical tasks (NCTM, 1989), guides that specify the student thinking those tasks generally surface, and suggestions for conducting discussions.

The degree and nature of teachers' use of curriculum materials is influenced by several factors such as what type and how much training teachers receive on the use of the curriculum materials, the teachers' perceptions as to the impact of those materials on student learning, and the alignment of the curriculum materials to the way they teach (Remillard & Bryans, 2004). How well teachers understand the curriculum and if they are given the amount of time needed to fully implement the curriculum have also been found to affect the degree and nature of teachers' use of curriculum materials (Collopy, 2003; Drake et al., 2014; Penuel et al., 2007).

Conclusion

Despite the new mathematical goals, a consistent description of mathematical processes in both the 1989 *Curriculum and Evaluation Standards* and 2000 *Principles and Standards*, and a redefinition of teacher and student roles, instruction in the mathematics classroom remains relatively unchanged (Hendrickson et al., 2008; Stigler & Hiebert, 1999). Providing a possible reason for the limited effect of the reform movement Chazan and Ball (1999) contend that teachers are merely being told what NOT to do in their classrooms. They argue that educators are often left "with no framework for the kinds of specific, constructive pedagogical moves that teachers might make." (p. 2). The *Comprehensive Mathematics Instruction* (CMI) Framework (Hendrickson et al., 2008) was designed to provide teachers with "specific, pedagogical assistance" based on a constructivist perspective. It in turn fosters and/or aligns with two means of assistance for teachers—effective professional development and reform-based curriculum materials (Ridgeway, 1998).

The teachers in this study were provided with the opportunity to attend a professional development related to the CMI Framework that also aligned with their district's new reform-based curriculum materials. This study seeks to examine the relationships between their perspectives about the framework and the curriculum, and their use of both in their classroom practices.

CHAPTER 3

Methods

Inasmuch as professional development and curriculum materials have been shown to influence teacher change and therefore, teacher practice, this study investigates the potential relationships that may exist between the frequency and quality of use of the CMI Framework, and the understanding, use frequency, and perceived usefulness of the *Investigations* curriculum. These variables were the primary issues of concern in this study and relationships were assumed to be bi-directional rather than directional. That is, it is possible the amount and quality of CMI Framework use is related to the amount of *Investigations* use, and the amount of *Investigations* use is associated with the amount and quality of CMI Framework use, or both. It should be noted that this work is the author's continuation of a previously initiated project. The focus group and Institutional Review Board approval took place prior to her involvement which began in the latter part of survey construction and continued through analysis and reporting.

Participants

Nearly all elementary grade teachers employed by the district from 2012 through 2015 participated in the 3-year *Comprehensive Mathematics Instruction (CMI)* professional development initiative designed to help teachers learn to teach mathematics using a guided inquiry approach. When it concluded, the district adopted a new mathematics curriculum (textbook), *Investigations in Number, Data and Space*, to support teachers in implementing the CMI Framework in their classrooms. At the end of the first year of *Investigations* implementation, May 2017, teachers and other district personnel were surveyed regarding the professional development and the new curriculum materials (the survey will be discussed in more detail in the next section). Forty-three teachers completed the survey, completely or in part, representing 27% of the potential 157 respondents, a response rate far below normally accepted response rates (McMillan & Schumacher, 1984). Thus, the response rates relative to each grade level and/or other job characterization were correspondingly low, particularly Special Education (one respondent with the exception of the first survey item), and there was considerable respondent attrition towards the end of the survey. As a result, it is difficult to characterize the entire district elementary teaching faculty based upon the results obtained from the survey, but they are nevertheless informative.

To preserve anonymity, respondents were not required to identify themselves by school, only by grade or other job description. Of the 43 teachers that responded, eight were kindergarten teachers, four were first grade teachers, seven were second grade teachers, 10 were third grade teachers, seven were fourth grade teachers, two were special education teachers, and five had other roles within the schools. Twenty-one of the participants had five or fewer years of teaching experience. Sixteen of the teachers had between 6-15 years of teaching experience and five of the teachers had been teaching 21 years or longer. One teacher declined to answer this question.

The survey was administered via Qualtrics with the link being sent to each of the five elementary school principals in the district. They were asked to invite teachers to respond to the survey while involved in a faculty meeting to ensure a high response rate. Unfortunately, the principals chose to email a communication to invite their teachers to complete the survey instead. This means of survey distribution was especially problematic because in order to avoid undue influence, principals were not allowed to monitor responses or response rates from their school, resulting in the low response rate indicated above. A complete copy of the final version of the survey can be found in the appendix.

Instrument/Data Sources

Survey construction began with a review of relevant research literature. Prior-obtained investigator knowledge was combined with the results of the literature review to create 12 potential factors of interest. These factors were used to create survey questions and an "Hypothesized Structural Model," as shown in Figure 4. The model represented conjectured relationships among the factors. The factors that organized the model then became "themes" about which multiple survey items were constructed. Therefore, four sources informed survey creation: a review of literature, investigator knowledge, focus group interviews, and the "Hypothesized Structural Model." Selected and constructed response items that potentially comprised the survey were then created. Table 1 identifies the themes and lists the number of selected (scaled) and teacher constructed short answer response items associated with each.

Figure 4

Hypothesized Structural Model

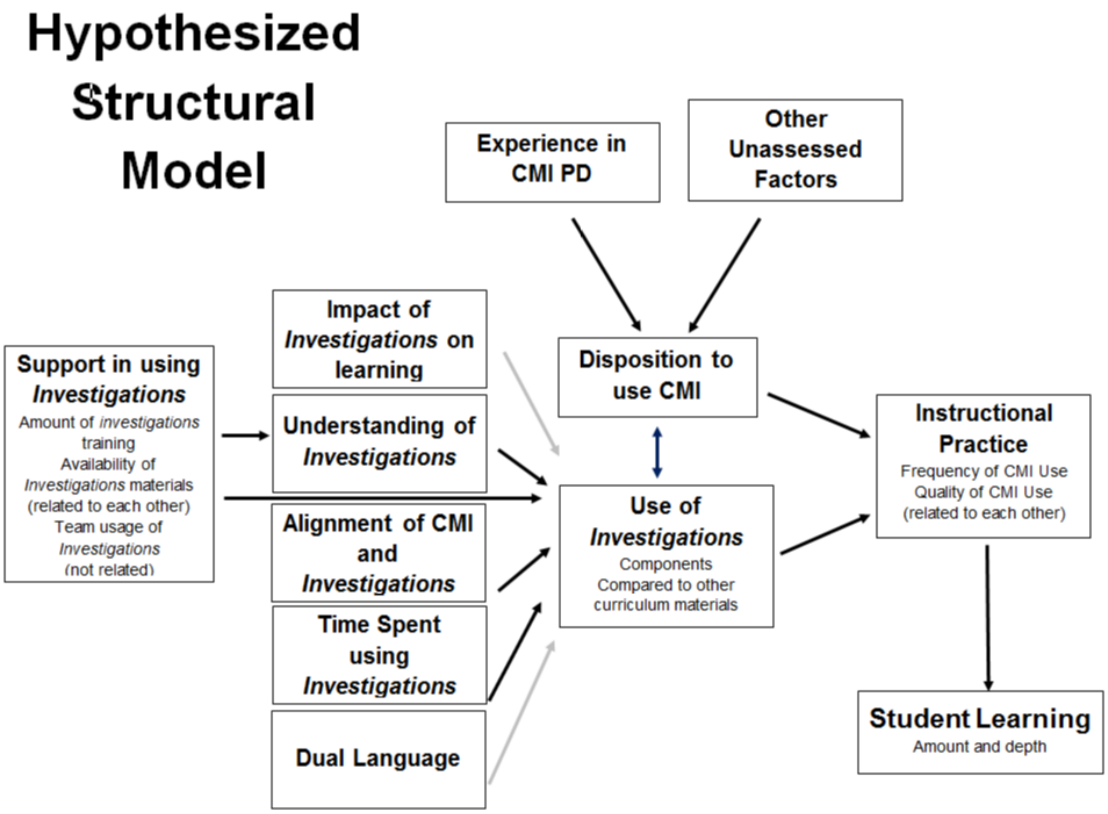


Table 1

Survey Item Distribution by Theme

Theme	Constructed Response	Selected Response
Alignment of teacher disposition with CMI	0	8
Quality of teachers' implementation of CMI	0	7
Degree of teachers' implementation of CMI	0	7
Degree of teachers' use of *Investigations*	1	12
Degree of helpfulness of *Investigations* in using CMI Framework	0	7
Degree of teachers' understanding of *Investigations* curricular design	0	4
Use of other curriculum materials, type and degree	4	0
Time required to implement *Investigations*	0	2
Degree of student learning via *Investigations*	0	3
Support for *Investigations* use	0	4
Dual language teachers	0	2
Experience in CMI Professional Development	0	5
Total	5	61

A think-aloud protocol was utilized to provide evidence of the content validity of the survey which helped to ensure that the survey respondents would interpret and respond to the survey items in a way that matched the intent. As a result, minor wording revisions were made, and an additional item was added. The final version of the survey consisted of five constructed response items and 61 selected response items, the majority of which used either five or six response categories. It should be made clear that the survey was a self-report instrument. Therefore, all the themes used to construct the survey represented the teachers' perspectives only. If a teacher omitted to answer a single question, the missing data was replaced with the mean (pairwise deletion/imputation).

Data Analysis

Bivariate correlations were calculated to investigate the strength of the relationship among the items associated across all 12 themes. Following this analysis, if any of the items within one theme possessed a low correlation ($r < .40$) with any other items within another theme, it was determined that those two themes were unrelated and they were removed from consideration. As this study is focused on the areas related to the teachers' implementation of the CMI Framework and their use of the *Investigations* curriculum materials, only the themes related to these topics were analyzed. Therefore, there were 5 themes and 36 items in the analysis. These themes will be described and outlined in the next chapter. Table 2 shows the correlations for the remaining five themes, which were:

- quality of teachers' implementation of the CMI Framework
- degree of teachers' implementation of the CMI Framework
- degree of teachers' use of *Investigations*
- degree of helpfulness of *Investigations* in using CMI Framework

- degree of teachers' understanding of *Investigations* curricular design

Items moderately correlated or higher ($r \geq .40$) are shaded.

Table 2

Bivariate Correlations Among Survey Items

	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	4
9	1																																				
1	.3	1																																			
1	.4	.60	1																																		
1	.4	.38	.4	1																																	
1	.3	.42	.4	.4	1																																
1	.3	.53	.5	.6	.7	1																															
1	.6	.49	.5	.6	.4	.6	1																														
1	.8	.40	.5	.4	.2	.3	.6	1																													
1	.4	.70	.6	.5	.4	.5	.5	.56	1																												
1	.4	.67	.7	.6	.4	.5	.5	.61	.8	1																											
1	.6	.35	.5	.7	.3	.4	.7	.77	.5	.6	1																										
2	.3	.48	.6	.5	.5	.5	.3	.43	.6	.5	.5	1																									
2	.4	.56	.5	.6	.7	.8	.6	.50	.6	.6	.6	.7	1																								
2	.7	.56	.6	.6	.3	.4	.6	.81	.8	.8	.8	.5	.6	1																							
2	.3	.47	.4	.1	.2	.3	.4	.59	.4	.5	.3	.2	.3	.5	1																						
2	.1	.68	.5	.2	.3	.3	.3	.37	.5	.6	.2	.3	.4	.4	.8	1																					
2	.2	.69	.5	.2	.3	.3	.4	.49	.5	.5	.3	.3	.4	.5	.8	.9	1																				
2	.3	.49	.4	.1	.1	.2	.3	.53	.3	.5	.2	.2	.2	.5	.8	.8	.8	1																			
2	.1	.61	.4	.1	.3	.3	.3	.39	.4	.4	.1	.2	.3	.4	.8	.8	.9	.8	1																		
2	.3	.59	.4	.2	.2	.3	.4	.56	.5	.5	.3	.1	.4	.5	.8	.8	.8	.8	.9	1																	
2	.3	.63	.5	.2	.2	.2	.4	.59	.5	.6	.4	.2	.3	.6	.8	.8	.8	.8	.8	.8	1																
3	.2	.50	.2	.4	.3	.5	.5	.14	.4	.4	.2	.2	.5	.3	.4	.5	.4	.3	.4	.4	.3	1															
3	.0	.42	.1	.3	.2	.5	.3	.07	.3	.3	.1	.1	.4	.2	.3	.4	.3	.2	.3	.3	.2	.8	1														
3	.0	.43	.0	.2	.0	.3	.4	.00	.4	.2	.2	.1	.4	.2	.2	.3	.3	.1	.2	.2	.2	.8	.7	1													
3	.1	.32	.1	.2	.0	.2	.3	.26	.3	.3	.2	-	.1	.3	.2	.2	.2	.1	.2	.2	.3	.4	.6	.4	1												
3	-	.32	.1	.0	.0	.2	.0	.22	.2	.1	.0	.0	.2	.1	.5	.6	.5	.4	.6	.5	.4	.5	.6	.4	.6	1											
3	-	.40	.1	.0	.0	.2	.2	.17	.2	.2	-	.0	.2	.1	.6	.6	.6	.6	.7	.6	.5	.6	.7	.5	.5	.8	1										
3	.3	.29	.3	.1	.0	.2	.1	.40	.2	.3	.2	.0	.2	.3	.4	.4	.4	.4	.4	.6	.5	.3	.3	.2	.2	.6	.5	1									
3	.0	.34	.2	.0	-	.3	.1	.30	.3	.3	.0	.1	.3	.2	.5	.6	.5	.4	.4	.5	.3	.4	.5	.3	.4	.7	.7	.6	1								
3	.2	.23	.1	.2	-	.2	.1	.19	.2	.2	.1	-	.1	.3	.2	.3	.2	.2	.3	.4	.3	.4	.4	.3	.4	.6	.4	.7	.6	1							
3	.2	.3	.2	.2	.0	.3	.3	.30	.3	.3	.1	.1	.3	.3	.4	.4	.2	.4	.3	.4	.3	.5	.5	.4	.5	.6	.6	.6	.8	.7	1						
4 0	.1 2	.53	.4 5	.2 6	.1 0	.3 8	.3 1	.32	.4 3	.5 3	.1 6	.1 4	.3 3	.3 7	.6 8	.7 6	.6 7	.6 6	.6 8	.7 6	.7 2	.4 8	.5 9	.3 9	.5 1	.6 7	.7 2	.6 6	.7 4	.6 6	.7 3	1					
4	-	.37	.2	.1	.1	.2	.0	.09	.2	.3	.0	.1	.2	.1	.3	.5	.3	.3	.4	.4	.3	.4	.4	.2	.5	.7	.6	.5	.6	.6	.7	.7	1				
4	-	.36	.3	.1	.2	.3	.2	.02	.3	.3	.1	.2	.3	.3	.5	.5	.5	.4	.6	.6	.5	.3	.4	.2	.4	.7	.6	.5	.7	.6	.6	.7	.7	1			
4	.3	.36	.2	.3	.2	.4	.1	.42	.3	.3	.2	.1	.3	.4	.4	.4	.4	.4	.5	.6	.5	.4	.3	.2	.2	.4	.4	.6	.4	.5	.4	.4	.2	.6	1		
4	.2	.29	.2	.2	.0	.2	.0	.44	.3	.3	.2	.1	.2	.3	.5	.5	.4	.4	.3	.4	.4	.3	.4	.1	.4	.7	.5	.7	.7	.7	.7	.7	.7	.7	.5	1	
4	.2	.25	.3	.4	.3	.5	.2	.42	.2	.2	.3	.3	.4	.4	.4	.4	.4	.4	.3	.5	.3	.4	.3	.1	.1	.5	.3	.5	.4	.4	.4	.4	.2	.5	.7	.6	1

Two themes, how well and how often the teacher feels the CMI Framework is implemented in their classroom were found to be highly related with 43 out of 49 (88%) correlations being above the .40 threshold. Therefore, they were combined to become one theme called CMI Implementation and included 14 items.

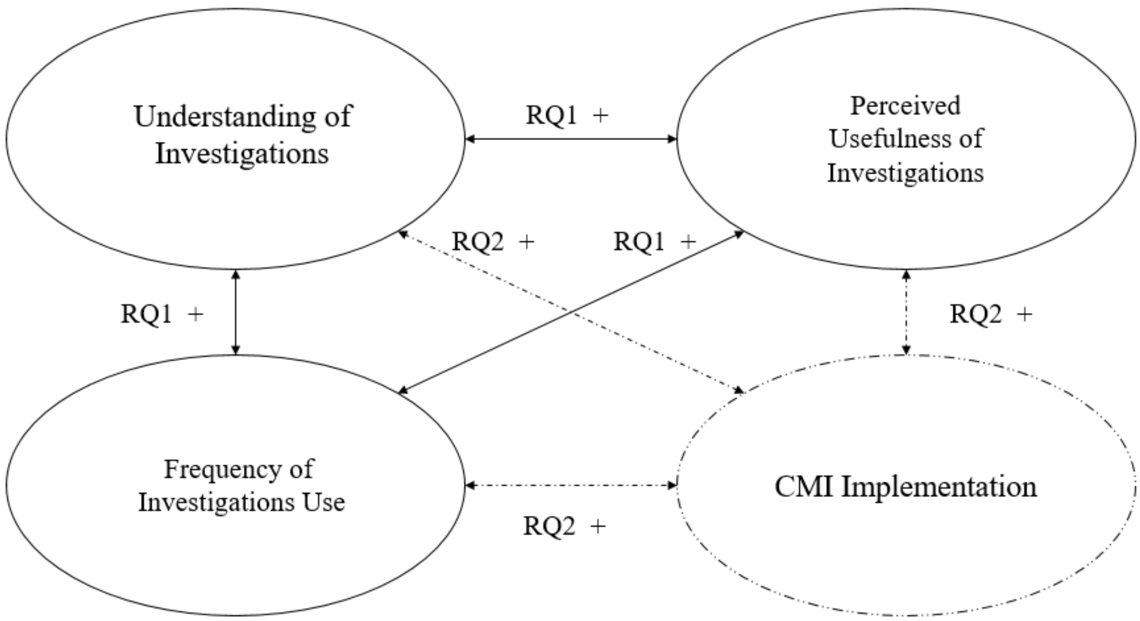
There remained three other themes, the teachers' perceived usefulness of *Investigations*, their understanding of *Investigations*, and the frequency of use of *Investigations*. Low correlations were found between two items within the Use of Investigations theme. After consulting with the elementary math specialist responsible for directing the implementation of *Investigations*, it was discovered that teacher use of the *Investigations* components represented by these items was low and so the three items were removed leaving ten items in this theme. One item was removed from the understanding of *Investigations* theme due to low correlations, leaving three items for analysis in that theme. Among these three themes, the correlations were analyzed, and it was found that the percentages of correlations above the .40 threshold between any two of them was below 70% so these three themes remained separate.

There was only one constructed response item within the remaining themes. It was part of the "Frequency of Use of *Investigations*" theme. Responses to that item will be examined later in order to illustrate the relationships in the empirical model.

These four themes were structured to create an empirical model (Figure 5) from the theoretical model (Figure 4) based on the hypothesis stated in Chapter 1. At this point in the study, the themes were once again termed as factors. A Principal Components Analysis (PCA) was conducted, one for each factor in the model, to determine the extent to which the factors were empirically supported using the rule (Guttman, 1954) that at least 50% of the item variance should be explained by the factor.

Figure 5

Empirical Model



In the first of the four themes, CMI Implementation, the PCA showed that 60% of total variance of these 14 items was explained by the factor, with an eigenvalue of 8.4. Loadings in the PCA component matrix ranged from .63 to .88. Thus, it was determined that empirical fit from these 14 items to the specific factor was adequate.

In the PCA of the teachers' perceived usefulness of *Investigations,* it was found that 87% of the total variance of these seven items was explained by the factor, with an eigenvalue of 6.1. Loadings in the PCA component matrix ranged from .91 to .95 revealing that the empirical fit from these seven items to the specific factor was adequate.

In the PCA of the teachers' understanding of *Investigations,* it was found that 87% of the total variance of these three items was explained by the factor with an eigenvalue of 2.6. Loadings in the PCA component matrix ranged from .92 to .96.

In the PCA of the teachers' frequency of *Investigations* use, it was found that 71% of total variance of these 10 items was explained by the factor, with an eigenvalue of 7.1. Loadings in the PCA component matrix ranged from .78 to .89

To address the research questions (Chapter 1) a series of bivariate correlations were run. In the first step, bivariate Pearson product-moment correlations (PPMC) were conducted among the four latent factors. In the second step, a series of partial correlations were conducted to determine:

1. The extent to which the bivariate relationships among *Investigations* factors persisted after accounting for other relationships among *Investigations* factors.
2. To what extent the bivariate relationships among the factors related to CMI Implementation and *Investigations* factors persist after accounting for other relationships.

Given the limitations in sample size and statistical power, PPMC was the only analysis that could have been conducted with validity to account for multi-collinearity among the factors in the model.

CHAPTER 4

Results

Responses to items within each theme were totaled and means and standard deviations were calculated (Tables 3 and 4). The tables are organized by the themes, which appear in the first column and are accompanied by an abbreviated version of the item. Note all themes shown here were assessed using Likert scale items with 5-point, uni-directional response categories that ranged from least positive on the left end of the scale to most positive on the right end.

Table 3

Descriptive Statistics for CMI Implementation Survey Items

Theme	Item No.	Items	n	Mean	SD
CMI Implementation	9	Teach lessons using the *Teaching Cycle*	40	2.43	.81
	10	Orchestrate engaging discussions	40	2.33	.73
	11	Organize discussion around student thinking	40	2.38	.70
How well do you implement the following components of the CMI Framework?	12	Present useful tasks for the *Launch* stage	40	2.38	.84
	13	Ask questions that probe student thinking	40	2.58	.71
	14	Understand and interpret student thinking to inform your instructional decisions	40	2.58	.90
	15	Teach the different *Learning Cycle* lesson types	40	2.38	1.00
CMI Implementation	16	Teach lessons using the *Teaching Cycle*	39	2.64	1.04
	17	Orchestrate engaging discussions	39	2.59	.79
	18	Organize discussion around student thinking	39	2.54	.85
How often do you implement the following components of the CMI Framework?	19	Present useful tasks for the *Launch* stage	39	2.56	.88
	20	Ask questions that probe student thinking	39	2.85	.81
	21	Understand and interpret student thinking to inform your instructional decisions	38	2.71	.77
	22	Teach the different *Learning Cycle* lesson types	39	2.62	.96

Note. For how well CMI is implemented:

0 = not very well, 1 = to a limited degree, 2 = somewhat, 3 = quite well, 4 = thoroughly

For how often CMI is implemented:

0 = never, 1 = rarely, 2 = sometimes, 3 = frequently, 4 = consistently

Teachers' perspectives on how well they currently implement the CMI Framework (Table 3) had a range of .25 (M = 2.44 high end of "somewhat"). "Orchestrate engaging discussions" had the lowest mean (M = 2.33 "somewhat") while the highest mean was found in two items, "Ask questions that probe student thinking" and "Understand and interpret student thinking to inform your instructional decisions" (M = 2.58 low end of "quite well"). The standard deviations in how well teachers feel they implement the CMI Framework components had a range of .30 (M = .81). "Teach the different *Learning Cycle* lesson types" had the highest standard deviation (SD = 1.00) and the lowest was found in "Organize discussion around student thinking" (SD = .71).

Teachers' perspectives on how often they currently implement the various components of the CMI Framework (Table 3) had a range of .31 (M = 2.64 low end of "frequently" range). "Ask questions that probe student thinking" had the highest mean (M = 2.85 "frequently") and the lowest mean was found in "Organize discussion around student thinking" (M = 2.54 low end of "frequently" range).

The standard deviations in the category related to their perspectives on how often they currently implement the CMI Framework had a range of .27 (M = .87). "Teach lessons using the *Teaching Cycle*" had the highest standard deviation (SD = 1.04) and "Understand and interpret student thinking to inform your instructional decisions" had the lowest (SD = .77).

It is worth noting that the highest means for both how well and how often the CMI Framework is implemented occurred in the items related to asking questions that enable the teacher to find out what students are thinking while the lowest means in these same two themes occurred in the items related to organizing and orchestrating student discussions.

The means in the themes related to *Investigations* (Table 4) had a range of 1.13 (M = 2.21). Items 23-29 indicate the extent to which respondents perceived *Investigations* as supportive of teaching based on the CMI Framework. The overall mean was 2.19 ("somewhat"). The range among means in this theme is small (.11) because all the response means fell within the "somewhat" range.

Table 4

Descriptive Statistics for Investigations Items

Theme	Item No.	Items	n	Mean	SD
Usefulness of *Investigations*	23	Design lessons using the *Teaching Cycle*	34	2.15	1.21
	24	Orchestrate engaging discussions	34	2.18	1.11
	25	Organize discussion around student thinking	34	2.15	1.10
To what extent does *Investigations* help you . . .	26	Present useful tasks for the *Launch* stage	34	2.26	1.05
	27	Ask questions that probe student thinking	34	2.21	1.15
	28	Understand and interpret student thinking to inform your instructional decisions	33	2.21	1.14
	29	Teach the different *Learning Cycle* lesson types	34	2.18	1.14
Understanding of *Investigations*	30	How well do you understand relationships between *Investigations* and the Utah Core	34	2.29	.94
	31	How well do you understand why specific math topics or objectives are repeated in *Investigations*	34	2.56	.75
	32	How well do you understand the order in which math topics or objectives appear in *Investigations*	34	2.00	.92
	33	To what extent do you teach the specific math topics or objectives in the order in which they appear in *Investigations*	34	2.56	1.08
Frequency of *Investigations* Use	34	Session Activities	31	2.10	1.25
	35	Session Discussions	31	1.97	1.14
	36	Math Workshop	31	2.10	1.19
	37	Session Follow-up	31	1.74	1.15
	38	Classroom Routines	31	2.13	1.26
To what extent do you use each of the following components of *Investigations*?	39	Teacher Notes	31	1.97	1.22
	40	Ongoing Assessment: Observing Students at Work	31	2.16	1.34
	41	End-of-Unit Assessments	31	1.90	1.58
	42	Technology	31	2.39	1.33
	43	Games	31	2.52	1.15
	44	Workbooks	31	2.26	1.26
	45	Manipulatives	31	2.87	1.15

Note. Usefulness of *Investigations*

0 = not at all, 1 = a little, 2 = somewhat, 3 = quite a bit, 4 = extensively

Understanding of *Investigations*

0 = not very well, 1 = to a limited degree, 2 = somewhat, 3 = quite well, 4 = thoroughly

Frequency of *Investigations* use

0 = never, 1 = rarely, 2 = sometimes, 3 = frequently, 4 = consistently

The mean of the teachers' understanding of the *Investigations* organizational structure ranged from 2.00 ("somewhat") in the order math topics appeared to 2.56 (low end of "quite well") in two items; why topics are repeated and the extent to which they cover material in the order presented by *Investigations*. It is interesting to note that the teachers' understanding of the order in which the topics/objectives appear is half a scale lower than the extent to which they follow the order of *Investigations.* This means the extent to which teachers follow the topic/objective order is greater than the extent to which they understand the order.

Assessing the extent to which teachers use *Investigations* was accomplished by combining assessments of their use of its individual components. Manipulatives are used most frequently (2.87, "frequently") and Session Follow-up the least (1.74, "sometimes"). The manipulatives and games were the only two components whose use fell into the "frequently" range. The remaining components all fell into the "sometimes" range. The greatest variability was found in this theme. Both the highest and lowest means were in this category.

Answers to the constructed response question regarding the teachers' frequency of use of *Investigations* were categorized and grouped by response type (Table 5). With the exception of two, the comments were relatively negative in nature. "Teacher feels unfamiliar with *Investigations"* and "Does not fit with current teaching practices" were commented on the most. However, there were three categories related issues relative to time, besides "Time – general" there were also responses related to both "Teacher preparation time," and "Classroom time." When combined, the issue of time was commented on the most. It could even be said that "Teacher feels unfamiliar with *Investigations*" was also an issue of time.

Table 5

Constructed Response Items – Frequency of Investigations Use

What are the reasons for the extent you do or do not use the components of *Investigations*?	Total
Teacher preparation time	2
Classroom time	5
Time - general	2
Teacher feels unfamiliar with *Investigations*	6
Students are confused	5
Does not fit with current teaching practices	6
Other - negative	2
Other – positive	2

Six Pearson product-moment correlation coefficients (PPMC) were computed to assess the relationships between the four themes, CMI Framework Implementation, teachers' perceived usefulness of *Investigations*, teachers' understanding of *Investigations*, and the frequency of use of *Investigations* (Table 6). The results of these correlational analyses indicated that 10 of the correlations were relatively strong ($r \geq .30$) and statistically significant ($p \leq .05$). There were some teachers that did not complete the entire survey. Therefore, it is noted that sample sizes are not consistent across all four themes and throughout the correlations performed.

Table 6

Simple and Partial Correlations

	Bivariate Relationships	Simple Correlation (n = 43)		Partial Correlation (n = 39)	
		r	*p*	*r*	*p*
RQ1	perceived usefulness X understanding	.400	.008	-.024	.884
	perceived usefulness X frequency of use	.590*	.000	.492	.001
	understanding X frequency of use	.545*	.000	.435	.001
RQ2	CMI Implementation X understanding	.392	.009	.266	.092
	CMI Implementation X frequency of use	.301	.050	-.129	.422
	CMI Implementation X perceived usefulness	.525*	.000	.441	.004

*Significant at $r > .50$

Partial correlations were computed to determine the relationships between each pair of themes while controlling for the remaining two themes (Table 5). The small correlations found between two pairs of themes, perceived usefulness of *Investigations* and understanding of *Investigations* as well as CMI Implementation and frequency of *Investigations* use have results that suggest they are unrelated to each other (-.024 and -.129).

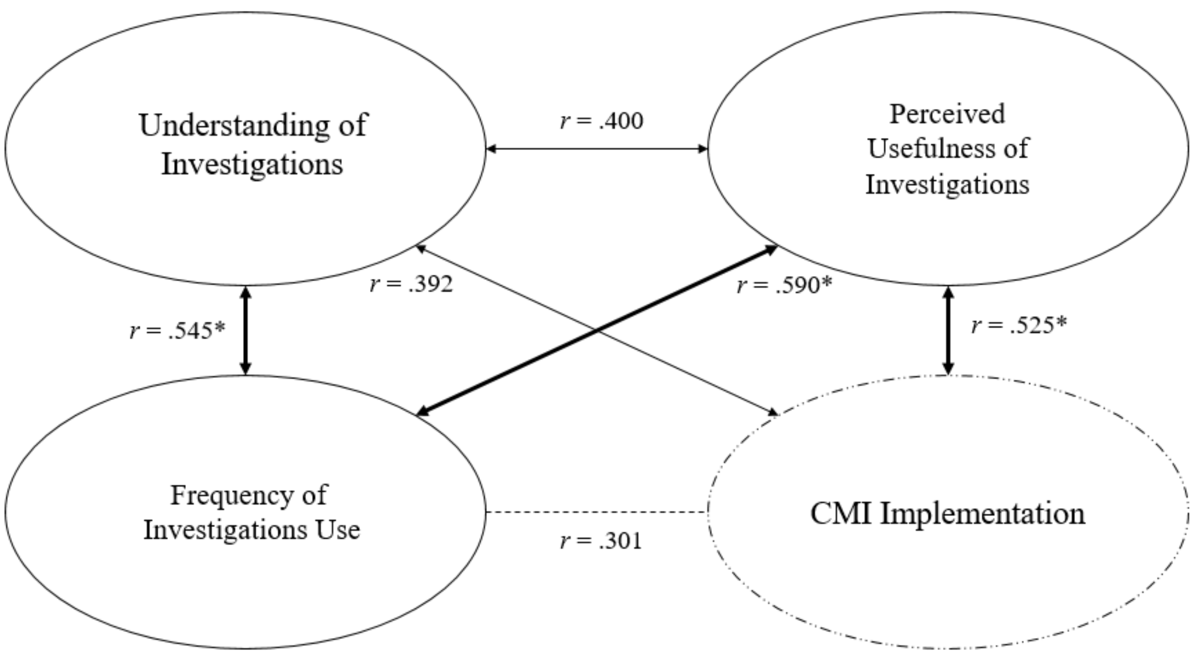
Interpretation

The simple bivariate correlation showed relatively medium (.50 - .69) or small (.30 - .49) positive and statistically significant associations between all six of the bivariate relationships. The strongest correlation was between the perceived usefulness of *Investigations* and the frequency of *Investigations* use. The weakest correlation was between CMI implementation and the frequency of *Investigations* use.

The partial correlations showed relatively medium, positive and statistically significant relationships among only three of the six relationships, the frequency of *Investigations* use with both perceived usefulness of *Investigations* and understanding of *Investigations* (Figure 6) while controlling for the other two items. Also showing positive associations was CMI implementation with perceived usefulness of *Investigations* while controlling for understanding of and perceived usefulness of *Investigations*. No significant relationship was found between CMI implementation and understanding of *Investigations.*

Figure 6

Bivariate Correlations Between Themes

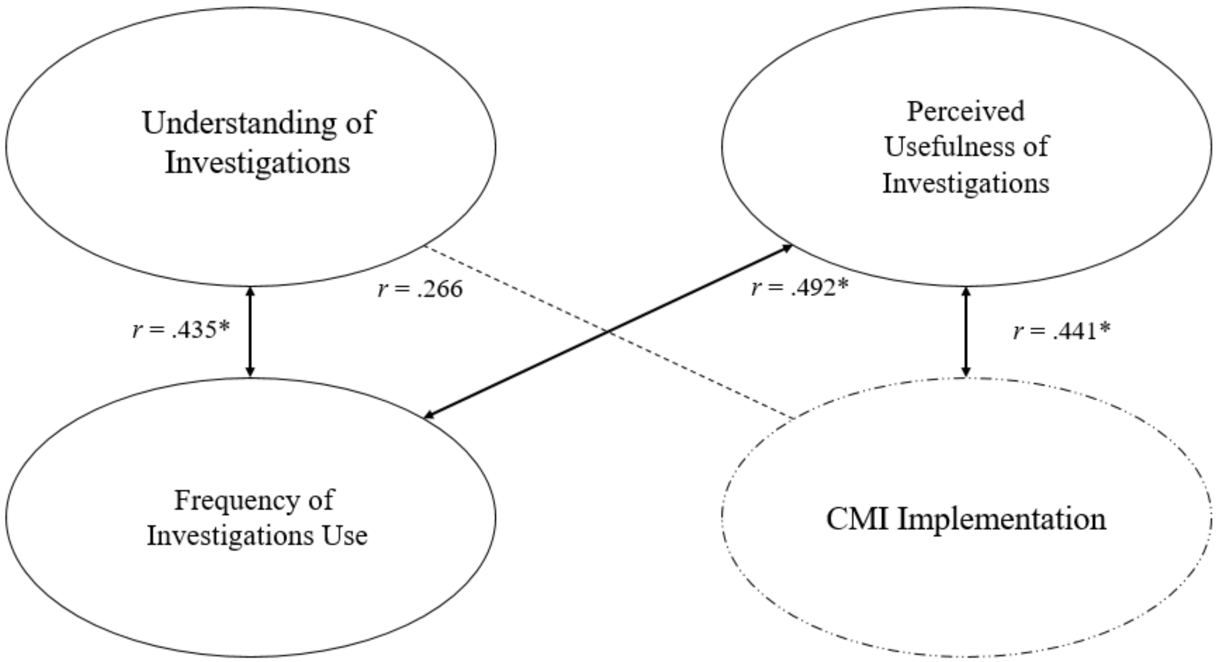


Note. *correlations statistically significant at the $p < .05$ level

The hypothesis that there would be relatively strong, positive and statistically significant relationships between the three *Investigations* themes held up except for the partial correlation between the perceived usefulness of *Investigations* and teachers' understanding of *Investigations* (Figure 7).

Figure 7

Partial Correlations Between Themes



Note. *correlations statistically significant at the $p < .05$ level, this figure does not include arrows for non-significant relationships.

The hypothesis that there would be relatively strong, positive and statistically significant relationships between the CMI implementation and the three *Investigations* themes was also correct except for the relationship between CMI implementation and the frequency of *Investigations* use.

Research Question 1

The first research question asked if there was a relationship between teachers' understanding, perceived usefulness, and use frequency of *Investigations*. Respondent answers indicated that there is a relatively strong, positive and statistically significant relationship between frequency of *Investigations* use and both understanding of *Investigations* and perceived usefulness of *Investigations*. However, there was no relationship between understanding of *Investigations* and perceived usefulness of *Investigations*.

Research Question 2

The second research question asked to what extent the teacher reported CMI implementation was related to their understanding, perceived usefulness, and use frequency of *Investigations*. After performing both simple and partial correlations, it was determined that there is a small positive relationship between the CMI implementation and the understanding of *Investigations* while controlling for frequency of use of and perceived usefulness of *Investigations*. There was a medium relationship between the CMI implementation and the perceived usefulness of *Investigations* while controlling for frequency of use and understanding of *Investigations*. However, no relationship was found between the CMI implementation and the frequency of *Investigations* use while controlling for the other two themes.

Hypotheses

The hypotheses were that there would be statistically significant and positive relationships among the themes related to CMI Implementation and *Investigations*. The data generally supported the hypotheses, with two exceptions. There was no statistically significant relationship between the understanding of *Investigations* and the perceived usefulness of *Investigations*, nor was there a statistically significant relationship between the frequency of *Investigations* use and CMI Implementation (Table 5).

When performing the simple correlations, all of the themes showed themselves to be related with either a small or a medium degree of magnitude. There was only one relationship with a small degree of magnitude and that was frequency of *Investigations* use and CMI Implementation. When the partial correlation was performed and this relationship controlled for the understanding of *Investigations* and the perceived usefulness of *Investigations*, no relationship was found.

There were two relationships with a medium degree of magnitude shown in the simple correlations, the understanding of *Investigations* when correlated with the perceived usefulness of *Investigations* and with CMI Implementation (Figure 6). However, when controlled for the other two themes, the understanding of *Investigations* and perceived usefulness of *Investigations* no longer had a significant relationship, but the understanding of *Investigations* and CMI Implementation did have a small magnitude of significance (Figure 7).

Three relationships were statistically significant with a large degree of magnitude when the simple correlations were performed, perceived usefulness of *Investigations* – with both frequency of *Investigations* use and CMMI implementation and also understanding of Investigations and frequency of *Investigations* use (Figure 6). After partial correlations, the same three relationships were still significant with a medium degree of magnitude.

CHAPTER 5

Discussion

Student achievement in mathematics has been a concern in the United States for decades (NCTM, 1980; 1989; 1991; 2000; 2014) and a lack of constructive professional development with specific ideas for what to do has been identified as a potential problem hampering the improvement of math instruction (Chazan & Ball, 1999). Additionally, the need for reform-based curriculum cannot be overlooked as even minimal use of a curriculum can influence teacher learning and therefore bring about a change in teaching (Remillard & Bryans, 2004). Research suggests that teachers need both adequate professional development and reform-based curriculum materials to facilitate changes in teaching practices that benefit student learning (Firestone et al., 2004; Ridgeway, 1998; Tarr et al., 2008).

Review of Purpose

For this study, teachers were provided with two means of assistance, professional development based on the CMI Framework and a new reform-based curriculum, *Investigations*. The purpose of this study was to examine the potential relationships between the implementation of the framework and the use of the new curriculum. Of particular interest was the relationship between the elements of the quality of use of the CMI Framework and the frequency and usefulness of *Investigations* that relate to a Vygotskian perspective. Use of *Investigations* can potentially provide support for elements of the CMI Framework that relate specifically to Vygotsky's theory relating to the use of language as a mediational tool and the promotion of discussion or collaboration between two or more individuals that Vygotsky (1986) speaks of when he refers to more knowledgeable others (MKOs). *Investigations* can assist teachers in helping students take the lead in collaborative conversations, used as a mediational tool, to increase and deepen their understanding of mathematics.

The following sections will summarize the Findings, discuss the potential explanations for the relationships that do and do not exist between the factors, and pose additional questions that could be addressed by further/subsequent studies. The discussion will begin by detailing the expected meaningful relationships between the teachers' self-reported usage of the CMI Framework (how well and how often) and the factors related to *Investigations* and then cover the lack of relationship between the CMI Framework and the frequency of *Investigations* use. This will be followed by a discussion of relationships found and not found between the individual factors related to *Investigations*. As the curriculum given to support the CMI Framework professional development, the relationships among the *Investigations* related themes could have an influence on the previous items. Finally, implications, areas for future studies, and limitations will be reported.

Summary of Findings

The purpose of this study was to investigate the potential relationships between the teachers' use of the CMI Framework implementation and the *Investigations* curriculum. After two years of reform-based professional development followed by a one-year implementation of *Investigations*, it was expected that meaningful relationships would be found between the frequency and quality of CMI Framework implementation and the understanding, use frequency, and perceived usefulness of the new curriculum. Of six expected relationships, only four were found to exist: those between CMI implementation and the perceived usefulness and understanding of *Investigations*, and the frequency of *Investigations* use and the perceived usefulness of and understanding of *Investigations*. Two expected relationships did not materialize: between the CMI Implementation and the frequency of *Investigations* use and between the perceived usefulness of *Investigations* and understanding of *Investigations*. A possible explanation for the lack of relationships could be that the teachers had only one year of using the *Investigations* curriculum. That is not a very long time, especially when considering that some portions of the curriculum materials did not arrive until shortly after the school year began. Additionally, while some of the teachers completed the preceding two years of CMI Framework professional development, there would be a small number of teachers recently hired who may not have completed all or any of the professional development. The survey was sent to all teachers, regardless of hire date. Thus, these teachers would be less likely to understand the connections between the curriculum and the framework.

CMI Framework

When surveyed, the teachers reported that they were using the CMI Framework often (between sometimes and frequently) and well (between somewhat and quite well). Standard deviations for these items were high, indicating a wide range of responses. Part of this could be due to the small sample size. It is also possible, because of the small sample size, that those who chose to respond were the ones who felt most strongly either in a positive or negative way. Therefore, responses would have fallen at either end of the spectrum. This was a self-reported survey, completed by the teachers after two years of CMI professional development followed by one year of using the new curriculum. The teachers should have acquired growth in CMI use slowly over the three years of professional development. They may not recognize the extent to which their teaching has changed. Using the components of the CMI Framework could, by this time, be so instilled within their everyday habits that they no longer think of these teaching techniques as "CMI", but instead, it is just the way they teach. Two elements of the CMI

Framework relate specifically to Vygotsky's theories regarding collaborative conversations in the classroom. It is interesting to note that these two survey items had the lowest average response in the CMI usage themes.

Investigations

The teachers indicated that they thought *Investigations* was somewhat useful, but suggested they had a good understanding of *Investigations* (between somewhat and quite well). However, they were still using *Investigations* only sometimes. There was a wide range of responses for all of these themes. The standard deviations were high, representing about half of the total scale. This polarized response could be an indication that teachers had a love or hate relationship with *Investigations* in that they found it useful for their teaching and embraced its components or they disliked the new curriculum for some reason and decided not to use it, continuing with whatever they were using previously. This survey was given to teachers at the end of just their first year of *Investigations* use. Although the majority of the materials arrived before the start of the school year, some delays occurred. While teachers had professional development to help them understand the CMI Framework, they did not have professional development assisting them with finding ways that *Investigations* could help them implement aspects of the framework. It is possible that the teachers were still too unfamiliar with the curriculum to make full use of the components. In addition, the teachers had already completed two years of professional development related to mathematics instruction. These elementary teachers teach multiple subjects. After two years of concentrating on mathematics, they may have felt the need to give attention to the other subjects they are responsible for teaching. A survey given after more time had passed might have produced different results, providing insight into the factors that influence teachers' use of new curriculum materials.

CMI Framework and Perceived Usefulness of Investigations

The expected meaningful relationship existed between CMI implementation (how well and how often) and the teachers' perceived usefulness of *Investigations*. This may be an indication that the teachers recognize the components of the CMI framework that exist within the *Investigations* curriculum. However, while teachers were asked how well *Investigations* helped them implement certain aspects of the CMI Framework, the survey did not extend to asking them if they could identify specific aspects of the CMI Framework within *Investigations* even if they chose not to use *Investigations* to help them accomplish those tasks.

CMI Framework and Understanding of Investigations

While there was a relationship between the teachers' perceptions related to their CMI use and their understanding of the *Investigations* curriculum, it was not as meaningful as other relationships. Time could be a factor in this slightly less meaningful relationship because the teachers took this survey after having less than one full year using the *Investigations* curriculum. To fully integrate a new curriculum, teachers need support and time to learn about the new curriculum and its approach. Teachers also need time to interact with the new curriculum with their colleagues, discussing the content and goals, and having time to discuss their teaching approaches (Remillard, 2005). One year does not seem a long enough time to do all of the above, especially in the situation related to this study where the teachers began the school year with less than 100% of the curriculum due to late delivery. Not all teachers use the curriculum provided by their district and so merely giving them a new curriculum is not enough to guarantee its use. It is also possible teachers may not have felt in need of all the components *Investigations* has to offer. If a teacher has already made math games to cover the standards they teach, they might not be willing to invest the time and money necessary to create new games, but might prefer instead to incorporate the games they already have into the new curriculum.

Moving beyond the time and implementation issues mentioned above, this study does not provide evidence for how the teachers used the tools provided (e.g., CMI development and *Investigations*), in ways that created new mediational means for learning. A more in-depth study including observations of what happened in the classrooms would be necessary in order to provide more information regarding this concept.

CMI Framework and Frequency of Investigations Use

The teachers appeared to recognize a connection between the CMI Framework and the *Investigations* curriculum. However, when it came to using the components of *Investigations*, the expected relationship did not materialize. While we were able to see that the teachers went through the training and applied at least some of their knowledge from the training in their classrooms, this study was not designed to provide evidence to show how the teachers learned to be more empowered when they applied the knowledge. The lack of connection might be partially explained by the timing associated with delivering the CMI professional development and providing *Investigation*s. If the teachers were interested in implementing what they learned in the professional development into their teaching, they are likely to have already chosen to make adaptations to their teaching methods immediately, using the materials available to them at that point.

Another point to consider is that the *Investigations* curriculum did not arrive until the year following the completion of the teachers' professional development. Therefore, it is possible they may not have been willing to invest even more time into changing their teaching to accommodate the new curriculum. This is especially true if the teachers felt that the purpose behind the curriculum change was to implement the CMI Framework. If *Investigations* was given to them as a tool to implement the framework, but they already felt that they were implementing the framework well, then they would likely lack the motivation to invest the time needed to make use of the new curriculum. With this mismatch of timing between when the teachers received training and the provision of the tools to implement what they learned, it is challenging to find meaningful correlations between their implementation of the framework and their use of the new curriculum.

Proponents of Vygotsky's theories might be interested to note that not only were the two items of CMI implementation that related to Vygotsky's theories on collaboration the ones with the lowest means, but the items relating to those same theories in the *Investigations* themes also had some of the lowest means (Tables 3 & 4). It is possible that if teachers struggled with the Vygotskian aspects of the CMI Framework that it affected their use of the curriculum provided. Although the analysis of the data does not suggest the directionality of this relationship and consequently a causal relationship cannot be supported, *Investigations* was brought in to support the teachers' use of the CMI Framework. If teachers are not using the curriculum, they are lacking in one of the supports of CMI Framework use and therefore may not be building their skill in this way of teaching. Hence, it is possible that a relatively low level in the quality of CMI implementation occurred or may have occurred because teachers do not think *Investigations* is very useful and they do not use it very much.

Perceived Usefulness and Frequency of Investigations Use

There was a meaningful relationship between the frequency of *Investigations* use and the perceived usefulness of *Investigations*. This was expected because teachers who do not see curriculum materials as useful will not use them. Teachers who see the usefulness of the curriculum materials provided for them are more likely to use them. Of the questions regarding the perceived usefulness of *Investigations*, half were specifically related to the teachers' CMI Framework training, as in, "To what extent does *Investigations* help you design lessons using the *Teaching Cycle*." However, teachers did not receive training on how to blend their CMI professional development and the new *Investigations* curriculum. Left on their own for this task, the varied results cannot be unexpected. Teachers' answers on open ended questions querying them regarding the reasons for using or not using the *Investigations* curriculum included frequent comments related to the time required to fully implement the new curriculum and the difficulty in blending CMI and *Investigations*. Because teacher change implementing a new curriculum such as *Investigations* may not appear until after the first year (Remillard & Bryans, 2004), a future survey, given after another year or two of use, might bring different results to these queries as teachers become more familiar with the Investigations curriculum.

Frequency of Use and Understanding of Investigations

The meaningful relationship between teachers' understanding of *Investigations* and their frequency of *Investigations* use was expected. This is likely a bi-directional relationship, the more teachers understand a specific curriculum, the more they will use it and the more they use a specific curriculum, the better they will understand it. If teachers are to use the CMI Framework and the *Investigations* curriculum in a synthesized way, they will need to have more goal directed activities allowing them to become more comfortable with and able to apply the tools in a meaningful way.

Along with the need for more theory application, transforming a new curriculum into their teaching practices requires time for teachers to interact with the curriculum both on their own and with their colleagues (Remillard, 2005). It is unclear how much time the teachers were given after receiving the *Investigations* curriculum to collaborate with their colleagues specifically on *Investigations*. As mentioned earlier, time to collaborate with colleagues is a fundamental element of implementing and using new curriculum materials (Remillard, 2005). It is possible that, given more time to collaborate with their fellow teachers on the usage of *Investigations*, that this relationship would be different.

Understanding of and Perceived Usefulness of Investigations

The lack of relationship between understanding of *Investigations* and perceived usefulness of *Investigations* can only be speculated on from the data gathered in this survey. It is possible that teachers believe they understand *Investigations* but do not perceive it as useful because they feel that they are already doing a good job of implementing the CMI Framework in their classrooms. The time required to implement *Investigations* was commented on in short answer questions of the survey. It is possible that the teachers do not believe that changing their teaching to accommodate usage of *Investigations* would be a beneficial use of their time as they have already implemented reform-based teaching strategies using the CMI Framework. This could possibly be a result of the order in which the professional development and curriculum were implemented. Teachers were not given the new curriculum until after the completion of the professional development. This would have reduced their time to explore the new curriculum with other teachers, a critical component of bringing about change in teaching practices (Remillard, 2005).

Implications

There are many possible scenarios of teacher reactions to professional development followed by a curriculum change. The most desirable teacher reaction to professional development is that they change their teaching throughout the professional development and when given the new curriculum, use it as a tool to continue improving their reform-based mathematics teaching. Another scenario is that teachers complete the professional development and change their teaching, but when they receive the new curriculum, feel that they have already made the change to reform-based mathematics teaching and do not believe it would be a constructive use of their time to incorporate the new curriculum. A further possibility is that teachers are not open to changing their mathematics instruction and continue as previously, despite professional development and curriculum changes. The survey used for this study did not provide enough information to do more than speculate on what scenario each teacher experienced; one of these or yet another, not considered option.

No school district wants to spend millions of dollars on a new curriculum, only to find it gathering dust on the shelves of classrooms or in school storage areas. The findings of this study suggest that even with professional development designed to align with the new curriculum, teachers may still choose to use or not use it. This study was conducted near the end of only the first year of curriculum use. It is possible that results would be different after more time.

Issues for Further Study

Related to the three possible scenarios of teachers' reaction to professional development mentioned above, the question remains regarding the best way to implement reform-based mathematics teaching through CMI Framework professional development and a new mathematics curriculum. The order in which these experiences are provided for teachers could well influence the success of bringing about the desired change in mathematics instruction. One option is that teachers receive the professional development first and then the new curriculum, as was done in this model. A second model would have the teachers receive the curriculum first and use it for a time prior to the professional development. The third option would be for the professional development and the curriculum to be rolled out simultaneously, a variation of this third option being to begin the professional development and bring in the new curriculum sometime within the process of completing the professional development. Future studies may want to look at situations where the curriculum was presented to teachers at the same time as the professional development. What changes might need to be made to the professional development if the curriculum was implemented first or at the same time?

Limitations

This study had some unavoidable limitations. The first limitation was sample size. The information gathered was self-reported by teachers anonymously with no way to track who had or had not completed the survey and therefore, no way to contact teachers who did not initially complete the survey, but may have done so if a reminder had been sent. The survey was limited to one school district and within this school district, students move on to another school after fourth grade. Therefore, respondents were limited to K-4 teachers and with some teachers not completing the survey, sample size was lower than desired. Had the sample size been much larger, the relationships among the variables could have been examined using a multivariate analysis through a regression framework rather than only the partial correlations that were used, perhaps leading to the discovery of more and/or stronger relationships. Indeed, other variables that were dropped from some of the initial models may actually have been shown to relate sufficiently to one or more variables and remained in the final model. Other factors, such as years of teaching experience, could have an effect and possibly influence the results. These are also issues for further investigation.

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APPENDIX

Teacher Survey

Years in this District including this year ___________________________

Grade assignment or role __________

To what extent do you agree with the following statements about mathematics teaching and learning?

1. Students should be regularly invited to solve complex, open-ended problems embedded in real-life contexts.

strongly disagree	disagree	disagree somewhat	agree somewhat	agree	strongly agree

2. Students are capable of discovering important mathematical ideas and solving mathematical problems without direct instruction from the teacher.

strongly disagree	disagree	disagree somewhat	agree somewhat	agree	strongly agree

3. The teacher's role in the mathematical classroom is that of co-learner and creator of mathematical community rather than sole knowledge expert.

strongly disagree	disagree	disagree somewhat	agree somewhat	agree	strongly agree

4. Students should have ready access to various mathematical tools and manipulatives to aid their problem-solving activity.

strongly disagree	disagree	disagree somewhat	agree somewhat	agree	strongly agree

5. Student-to-student interaction, i.e., discussion will facilitate the learning of mathematics.

strongly disagree	disagree	disagree somewhat	agree somewhat	agree	strongly agree

6. Assessment of student learning should integrate with instruction, allow for multiple levels of performance, and be relevant to students' lives.

strongly disagree	disagree	disagree somewhat	agree somewhat	agree	strongly agree

7. Students should have access to multiple strands of mathematical knowledge, not just numbers and operations.

strongly disagree	disagree	disagree somewhat	agree somewhat	agree	strongly agree

8. Learning to make connections, reason, and explain one's thinking is at least as important as memorizing basic facts and learning computational algorithms?

strongly disagree	disagree	disagree somewhat	agree somewhat	agree	strongly agree

Generally speaking, how <u>well</u> do you implement the following components of the CMI Framework?

9. Teach lessons using the *Teaching Cycle* (Launch – Explore – Discuss).

not very well	to a limited degree	somewhat	quite well	thoroughly

10. Orchestrate a discussion in a way that engages most of the students most of the time.

not very well	to a limited degree	somewhat	quite well	thoroughly

11. Organize the sharing in a discussion so that the thinking of the students builds on each other.

not very well	to a limited degree	somewhat	quite well	thoroughly

12. Find, create, or modify useful tasks to present in the *Launch* stage.

not very well	to a limited degree	somewhat	quite well	thoroughly

13. Ask questions that enable you to find out what students are thinking.

not very well	to a limited degree	somewhat	quite well	thoroughly

14. Understand and interpret student thinking to inform your instructional decisions

not very well	to a limited degree	somewhat	quite well	thoroughly

15. Teach different types of lessons according to the *Learning Cycle* (Develop Solidify-Practice).

not very well	to a limited degree	somewhat	quite well	thoroughly

How <u>often</u> do you implement the following components of the CMI Framework?

16. Teach lessons using the *Teaching Cycle* (Launch – Explore – Discuss).

never	rarely	sometimes	frequently	consistently

17. Orchestrate a discussion in a way that engages most of the students most of the time.

never	rarely	sometimes	frequently	consistently

18. Organize the sharing in a discussion so that the thinking of the students builds on each other.

never	rarely	sometimes	frequently	consistently

19. Find, create, or modify useful tasks to present in the *Launch* stage.

never	rarely	sometimes	frequently	consistently

20. Ask questions that enable you to find out what students are thinking.

never	rarely	sometimes	frequently	consistently

21. Understand and interpret student thinking to inform your instructional decisions

never	rarely	sometimes	frequently	consistently

22. Teach different types of lessons according to the *Learning Cycle* (Develop Solidify-Practice).

never	rarely	sometimes	frequently	consistently

To what extent does *Investigations* help you . . .

23. Design lessons using the *Teaching Cycle* (Launch – Explore – Discuss)

not at all	a little	somewhat	quite a bit	extensively

24. Orchestrate a discussion in a way that engages most of the students most of the time.

not at all | a little | somewhat | quite a bit | extensively

25. Organize the sharing in a discussion so that the thinking of the students builds on each other.

not at all | a little | somewhat | quite a bit | extensively

26. Find or create useful tasks to present in the *Launch* stage.

not at all | a little | somewhat | quite a bit | extensively

27. Ask questions that enable you to find out what students are thinking.

not at all | a little | somewhat | quite a bit | extensively

28. Understand and interpret student thinking to inform your instructional decisions.

not at all | a little | somewhat | quite a bit | extensively

29. Teach different types of lessons according to the *Learning Cycle* (Develop-Solidify-Practice).

not at all | a little | somewhat | quite a bit | extensively

How well do you understand . . .

30. The relationship between *Investigations* and the Utah Core.

not very well | to a limited degree | somewhat | quite well | thoroughly

31. The reason why specific math topics or objectives appear multiple times throughout the year in *Investigations*.

not very well | to a limited degree | somewhat | quite well | thoroughly

32. The order in which specific math topics or objectives appear as taught throughout the year in *Investigations*.

not very well | to a limited degree | somewhat | quite well | thoroughly

33. To what extent do you teach the specific math topics or objectives in the order in which they appear in *Investigations*?

never rarely sometimes frequently consistently

To what extent do you use each of the following components of *Investigations*?

34. Session Activities

never rarely sometimes frequently consistently

35. Session Discussions

never rarely sometimes frequently consistently

36. Math Workshop

never rarely sometimes frequently consistently

37. Session Follow-up

never rarely sometimes frequently consistently

38. Classroom Routines

never rarely sometimes frequently consistently

39. Teacher Notes

never rarely sometimes frequently consistently

40. Ongoing Assessment: Observing Students at Work

never rarely sometimes frequently consistently

41. End-of-Unit Assessments

never rarely sometimes frequently consistently

42. Technology

never rarely sometimes frequently consistently

43. Games

never rarely sometimes frequently consistently

44. Workbooks

never rarely sometimes frequently consistently

45. Manipulatives

never rarely sometimes frequently consistently

46. What are your reasons for the extent to which you use or do not use the above components? (short answer response)

Assuming you use *Investigations* on a regular basis . . .

47. At this point in the school year, how does the amount of time you spend preparing to teach math compare to the amount of time you used to spend using a previous text or other materials?

Much less less about the same more a great deal more (not applicable)

48. At this point in the school year, how does the amount of time you spend teaching math compare to the amount of time you used to spend using a previous text or other materials?

Much less less about the same more a great deal more (not applicable)

49. How does the amount of learning your students acquire while using *Investigations* compare with the amount of learning your former students acquired when you used a previous text or other materials?

Much less less about the same more a great deal more (not applicable)

50. How does the depth of learning your students acquire while using *Investigations* compare with the amount of learning your former students acquired when you used a previous text or other materials?

Much less less about the same more a great deal more (not applicable)

51. How does the number of your students who are successful in math using *Investigations* compare with the number of your former students who were successful when you used a previous text or other materials?

Much less	less	about the same	more	a great deal more	(not applicable)

52. What portion of your math instruction is supported by *Investigations,* by *Envision*, and by other sources including your own creations? (short answer, use fractions)

52a. If you still use *Envision*, what aspects of those resources do you use? (short answer)

52b.. If you included other as part of your answer to item 51, what other sources support your math instruction? Please indicate if these materials are CMI based or not. (short answer).

53. What is your reason for your answers to 52a & 52b? (short answer)

54. How is the way you use *Investigations* different from the way you have used other resources and textbooks in the past, if at all? (short answer)

55. What is your impression of the amount of training you have received in learning to use *Investigations?*

Not enough	about the right amount	too much

56. In general, how much does your grade level team (or other colleagues who have a job like yours) use *Investigations* in their math instruction?

never	rarely	sometimes	frequently	consistently

57. How much do you use *Investigations* compared to your grade level team (or other colleagues who have a job like yours) generally speaking?

much less	less	about the same	more	much more

58. To what extent do you feel you were coached on the implementation of the *Investigations* curriculum?

Not enough	about the right amount	too much

59. What is your role in the dual language program?

Spanish	English	no direct involvement

60. If you responded “Spanish” or “English” to #59, what is your role or responsibility in teaching math?

primary	supportive	only math teacher	no math responsibility

61. How effective were the facilitators who taught you the CMI professional development?

not effective	slightly effective	somewhat effective	effective	quite effective

62. How well organized were the CMI professional development sessions?

not organized	slightly organized	somewhat organized	organized	well effective

63. How helpful were the facilitators to your learning in the CMI professional development?

not helpful	slightly helpful	somewhat helpful	helpful	quite helpful

64. To what extent do you feel you were coached on the use of the CMI Framework?

Not enough	about the right amount	too much

65. How successful were the facilitators in promoting <u>active participation</u> in the CMI professional development?

not successful	slightly successful	somewhat successful	successful	quite successful

66. How respectful of student comments and questions were the facilitators in the CMI professional development?

not respectful	slightly respectful	somewhat respectful	respectful	quite respectful

67. Did you complete a survey similar to this one last year?

Yes	No

68. Which school do you teach at? (short answer)