CEME

Technical Report

CEMETR-2010-04
AUGUST 2010

The Center for Educational Measurement and Evaluation

MSP Grant Project "Content Development for Investigations" (CoDE: I). Year One Summative Report

Chuang Wang
Jennifer R. McGee
Richard G. Lambert

RICHARD LAMBERT
CHUANG WANG
MARK D'AMICO
SERIES EDITORS

A PUBLICATION OF
THE CENTER FOR
EDUCATIONAL
MEASUREMENT
AND EVALUATION

CEME
The Center for Educational Measurement and Evaluation
College of Education
UNC CHARLOTTE

MSP Grant Project CoDE:I Year One Summative Report

Chuang Wang

Jennifer R. McGee

Richard G. Lambert

Center for Educational Measurement and Evaluation

Department of Educational Leadership

University of North Carolina at Charlotte

MSP Grant Project CoDE:I Year One Summative Report

The following report presents findings from the external evaluation of the MSP Grant Project entitled, “Content Development for Investigations” (CoDE:I).

Professional Development, Teacher Beliefs, Practices, Content Knowledge and Student Learning Outcomes

Teacher Professional Development (PD) provides teachers with continued learning opportunities in order to hone their craft and support increased student outcomes (Blank & de Las Alas, 2009; Yoon, Duncan, Lee, Scarloss, & Shapley, 2007). Effective PD programs have been linked to teachers’ shifts towards more student-centered beliefs and classroom practices (e.g., Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009; Fennema et al., 1996; Garet et al., 2001; Heck et al., 2008; Loucks-Horsley et al., 2009).

Research indicates that effective PD programs:

- address deficits in student learning outcomes (Loucks-Horsley et al., 2009; Wilson & Berne, 1999);
- provide teachers with ownership of their activities (Loucks-Horsley et al., 2009);
- promote collaboration (Penuel, Fishman, Yamaguchi, & Gallagher, 2007, Suppovitz, 2003);
- address both content and pedagogy (Garet, Porter, Desimone, Birman, & Yoon, 2001; Heck, Banilower, Weiss, & Rosenberg, 2008);
- support reflections about teachers’ classroom practices (Guskey, 2003);
- and include ongoing support during the year.

These characteristics embody a learner-centered approach to PD (NPEAT, 2000). Teachers’ perceptions of or reactions to PD are an important research area (Guskey, 2000). If teachers perceive PD as not useful, they are unlikely to modify their instructional practices (Loucks-Horsley et al., 2009). Further, teachers' belief about the curriculum and related PD greatly influences their instruction (Remillard, 2005).

Teacher beliefs towards mathematics teaching have also been associated with instructional practices (Fennema et al., 1996), use of curricula (Stein & Kim, 2008), and willingness to enact student-centered pedagogies (Heck et al., 2008). Teachers' use of student-centered pedagogies has found to significantly increase student achievement and conceptual understanding (Carpenter, Fennema, & Franke, 1996; Stigler & Hiebert, 1999). Further, studies have found that students whose teachers have deeper content knowledge outperform their peers (Hill, Rowan, & Ball, 2005).

Program Evaluation

Program evaluation differs from academic research in that program evaluation is usually to provide information about what works and how the program works to program developers, policy-makers, sponsors, field-practitioners, and stakeholders of educational programs whereas academic research is typically geared towards theory-development (Henry & Mark, 2003). Program evaluators are service-oriented and are responsible to help stakeholders by providing feedback about how to modify or improve the program process (Fitzpatrick, Sanders, & Worthen, 2004). Program integrity, or fidelity of implementation, is the major concern in evaluating the effectiveness of a program and is defined as "the extent to which the critical components of an intended program are present when that program is enacted" (Century, Rudnick, & Freeman, 2010, p. 202).

Many approaches were taken in the literature to measure the fidelity of implementation, one of which is the *Five Dimensions Approach* (Dane & Schneider, 1998). Through a review of

162 studies, Dane and Schneider (1998) identified five dimensions to measure the fidelity of implementation: adherence, exposure, quality of delivery, participant responsiveness, and program differentiation. Another approach, *Critical Components,* focused program components and suggested essential elements that have to be measured (Hall & Hord, 1987). Still another approach, *Structure and Process Approach,* organized the fidelity criteria into two categories: program components (structure) and delivery (process) (Mowbray, Holter, Teague, & Bybee, 2003; Wang, Nojan, Strom, & Walberg, 1984). Recently, many scholars (e.g., Century et al., 2010; Lynch & O'Donnell, 2005; Ruiz-primo, 2005) called for a combination of frameworks to guide program evaluation studies.

Multiple evaluation designs were also discussed in the literature: experimental designs with randomized field trial (Eisenhart & Towne, 2003) and quasi-experimental designs with matched group comparisons, time series designs, or regression discontinuity methods (Shadish, Cook, & Campbell, 2002). The trade-offs of choosing various designs are also discussed. For example, highly controlled experimental designs have limited external validity because the unrealistic experimental settings are rarely met in educational environments while quasi-experimental designs reduces internal validity because of the possible impact of confounding variables that is not under control of the program evaluators (Rossi, Freeman, & Lipsey, 1999). Considering the social, organizational, and policy environments of educational PD, Chatterji (2004) proposed the ETMM design that uses a long-term plan, systemic and site-specific formative and summative evaluation phases, documentation and selection of treatment and interaction variables, combination of quantitative and qualitative methods, and explanation of causality in the local context. This report adopted the ETMM design to evaluate a PD program targeted to develop standards-based mathematics teachers.

Methods

Context

Participants in this study were elementary school teachers in a year-long Mathematics Science Partnership (MSP) grant designed to support their use of a standards-based mathematics curriculum. Specifically, the PD focused on building teachers' knowledge of mathematics content and pedagogies with focus on a standards-based curriculum, *Investigations in Number, Data, and Space (Investigations)*. *Investigations* includes tasks that are open-ended and align to the National Council for Teachers of Mathematics (NCTM) *Principles and Standards*. Students are expected to analyze problems, determine appropriate problem solving strategies, and justify their processes. Similar to most standards-based curricula, teachers pose tasks, scaffold students' work, and facilitate discussions about students' strategies and the mathematics concepts (Mokros, 2003).

Teachers participated in 84 hours of PD between July, 2009 and April, 2010. During the summer of 2009 teachers completed a 60 hour Summer Institute, in which they completed mathematical tasks focused on number sense and algebra, and examined how the mathematical concepts they were working on were taught in the *Investigations* curriculum. During the school year, teachers attended 4, 6-hour follow-up sessions focused on issues related to teaching with *Investigations*.

Participants

Fifty-three K-5 teachers participated in this study. All teachers were certified to teach elementary schools. Thirty-two teachers were from a large urban school district (District A) and the remaining 21 teachers were from a neighboring suburban school district (District B). Thirty-seven percent (n = 20) hold only a bachelor's degree, 30% (n = 16) hold a master's degree, and one teacher holds a bachelor's degree and certification specific to the content area. The rest of the participants did not report their highest degree held. Eighty-seven percent (n = 46) identified as Caucasian while 13% (n = 7) identified as African American.

Participants also included 688 students. Gender and ethnicity were reported by teachers for their aggregate classrooms. Fifty percent (n = 344) of the students were female and 50% (n = 344) were male. Thirty-nine percent (n = 268) of the students were Caucasian, 34% (n = 234) were African American, 20% (n = 138) were Hispanic, 4% (n = 28) were Asian, and 3% (n = 21) were identified by their teachers as "Other." Fourteen percent (n = 96) were identified as Limited English Proficient (LEP) and Ten percent (n = 69) were identified as having Individualized Education Plans (IEP).

In school district B, 29 Grades 3-5 teachers and 744 students served as the comparison group. The distribution of gender and ethnicity are very close between the comparison group and the treatment group, but differences were noticed for the distribution of grade levels, $\chi^2(2, n = 934) = 28.66$, $p < .001$. In the comparison group, there are 358 (48%) female and 386 (52%) male students; 318 (43%) Caucasian, 182 (24%) Hispanic, 178 (24%) African American, 59 (8%) multiracial, and 7 (1%) Asian students; 253 (34%) Grade 3, 233 (31%) Grade 4, and 258 (35%) Grade 5 students. In the treatment group, there are 91 (48%) female and 99 (52%) male students; 87 (46%) Caucasian, 43 (23%) Hispanic, 44 (23%) African American, 12 (6%) multiracial, and 4 (2%) Asian students; 72 (38%) Grade 3, 24 (13%) Grade 4, and 94 (49%) Grade 5 students. Greater portion of Grade 5 students and smaller portion of Grade 4 students were in the treatment than in the control group. No comparison group from school district A was used because these data were not available at the time of this report.

Design

The ETMM design was used to evaluate the program using both quantitative and qualitative data. Working together with district mathematics curriculum coordinators, mathematics education professors, and PD developers in monthly leadership meetings, we identified four key components of the PD during the first year: (a) teacher content knowledge in teaching mathematics; (b) teacher beliefs about teaching and learning mathematics, (c) instructional practices in teaching mathematics; and (d) impact of teacher beliefs and practices on student learning outcomes in mathematics.

Data Collection Methods

Long-time engagement and multiple instruments were used to collect data for the formative and summative evaluations. Teacher beliefs, practices and mathematics content knowledge were measured using three pre and post test instruments. Teachers' implementation of new knowledge and skills from the PD, as well as their experiences with the PD and their fidelity of implementation of Investigations were assessed using classroom observations, teacher interviews, and secondary data. Student achievement was measured using end of unit assessments from Investigations given before and after 3 specific units in the curriculum throughout the year.

Teacher instruments. All teacher-participants completed three pre-project and post-project instruments: a Teacher Beliefs Questionnaire (TBQ; Appendix A), a Teacher Practices Questionnaire (TPQ; Appendix B), and a Content Knowledge for Teaching Test (Appendix C). The TBQ examined teachers' espoused beliefs about mathematics, mathematics teaching and mathematical learning (Swan, 2007). For each of those three dimensions, teachers reported the percentage to which their views align to each of the transmission, discovery, and connectionist views. The sum of the three percentages in each section is 100. Teachers were coded as discovery/connectionist if they indicated at least 45% in either discovery or connectionist (Swan, 2007). The TPQ examined participants self-report about instructional practices related to their mathematics teaching (Swan, 2007). Each of the items reflects either student-centered or teacher-centered pedagogies. Teachers identified their instructional practices on a 5-point Likert scale, where 0 represents “none of the time” and 4 represents “all of the time.” Teachers with a mean score of 2.00 or less were coded as “student centered” and teachers with a mean score of 2.01 or more were coded as “teacher centered.” Content Knowledge for Teaching Test (see sample in Appendix C) measure teachers’ knowledge of mathematics content and knowledge of students and content (Hill, Rowan, & Ball, 2005). For each teacher, the number of correct items was recorded.

Observations. Twenty-one of the participants were observed once and eighteen were observed twice, in order to examine the fidelity of curriculum implementation. Teacher schedules and availability limited observations of some participants. Before and after the observation, teachers were asked to answer questions about their lesson (see Appendix D). These questions provided a framework for what would be occurring during the observation and hearing participants’ reaction to the lesson. The graduate research assistant conducted and scribed every observation, noting specific interactions between the teacher and student, levels of questioning used by the teacher (level 1= answer, level 2 = process, level 3 = reasoning), fidelity of implementation of the *Investigations* curriculum, and the classroom environment.

Interviews. Participants also participated in a two-part interview. The protocol (see Appendix E) was sent to each participant via email. A follow-up phone interview was conducted with each participant.

Secondary data sources. Other data was also used to verify findings. Participants completed a Leadership Log (Appendix F), exit tickets from the summer PD, email conversations, and face-face conversations between the researchers and the participant.

Student achievement measures. The student achievement measures were end-of-unit assessments from the *Investigations* curriculum (Russell & Economopolous, 2007). Three units, which were most closely associated with the professional development, were assessed from each grade level and each unit lasted between 3 and 5 weeks. Teachers administered these assessments before teaching the unit (pre-tests) and immediately after completing the unit (post-tests). One of the project evaluators used a teacher-created rubric to score each assessment and converted scores to a percentage. Gain scores were used in the analyses. State mandated standardized end-of-Grade (EOG) assessment data from school district B were also used.

Data Analysis

The multiple sources of data listed above were used to triangulate the results. T-tests and analysis of variance (ANOVA) were used to examine group differences and Hierarchical linear modeling (HLM) were used to analyze the student data nested within teacher variables to account for the within- and between-group variances. Constant comparison method was employed to identify emerging themes from observation field notes, transcribed interviews, and teacher on-line discussion, face-to-face conversations, and email communications.

Results

Influence on Teacher Beliefs

Thirty eight teachers completed both the TBQ and the TPQ for the beginning and end of Year One. Results from the TBQ showed that from the beginning to the end of the first year, 7 teachers changed their beliefs about teaching mathematics from discovery/connectionist orientation to transmission orientation whereas 22 remained unchanged. Out of these seven teachers, six of them taught kindergarten and second grade whereas one taught fourth grade. Meanwhile, 9 teachers changed their beliefs about teaching mathematics from transmission orientation to discovery/connectionist orientation. Out of these nine teachers, four taught Grades K-2 whereas five taught Grades 3-5.

As for their beliefs toward learning mathematics, 26 teachers remained unchanged while 8 teachers (one taught fourth grade and seven taught kindergarten and first grade) changed from discovery/connectionist orientation to transmission orientation and 4 teachers (two taught Grades 3 & 5 and two taught kindergarten and first grade) changed from transmission orientation to discovery/connectionist orientation. With respect to teacher's beliefs about mathematics, 25 teachers remained unchanged while 8 teachers (four taught kindergarten and second grade while four taught third and fourth grades) changed from discovery/connectionist orientation to transmission orientation and 5 teachers (four taught kindergarten and first grade while one taught third grade) changed from transmission orientation to discovery/connectionist orientation.

Influence on Teacher Practices

As for teacher practices measured by the TPQ, 40 teachers were identified with student-centered classroom practices and 12 teachers were identified with teacher-centered classroom practices at the beginning of the year. Only 39 out of the 52 teachers completed the post survey at the end of the year. Out of these 39 teachers, 34 were identified with student-centered classroom practice whereas 5 remained to be identified with teacher-centered classroom practice. That is to say, 29 remained student-centered and 5 changed from teacher-centered to student-centered classroom practices.

Influence on Mathematical Content Knowledge for Teaching

The Content Knowledge Test was completed by 35 teachers at the beginning and end of the year. Gain scores were completed by subtracting pre-test scores from pos-test scores. The mean of the gain scores was 2.34 with a standard deviation of 5.37. The minimum gain score was -12.00 and the maximum gain score was 11.00. When the gain scores were compared between the two school districts, the mean gain score for teachers in School District A (n = 17, M = 3.82, SD = 4.20) was not statistically significantly different from that for teachers in School District B (n = 18, M = 0.94, SD = 6.07), t (33) = 1.62, p = .11. The effect size measured by Cohen's (1988) d was medium (d = 0.55). Repeated measures ANOVA did not reveal any statistically significant differences in the interaction between school system and time, F (1, 33) = 2.63, p = .11, or between school districts, F (1, 33) = 0.26, p = .62, but a significant increase of teacher content knowledge, F (1, 33) = 7.21, p = .01. This result suggests that the PD was successful in increasing teacher's content knowledge in teaching mathematics in general.

Influence on Student Learning Outcomes

Student assessment gain scores (post-test minus pre-test) were presented in Table 1. Although there is a general trend of increasing average gains from the first round to the third round as the teacher participants are more exposed to the PD, negative gains were also observed.

Two-level hierarchical linear models were used to examine the association between the change of teacher-level variables (teacher beliefs, practices, and content knowledge) and student gain scores for each round of assessments. Parameter estimates of these models were presented in Table 2. The gain of teacher content knowledge in mathematics is not statistically significantly related to student gains during the second or third round, but was negatively associated with student gains in the first round. This means that students taught by teachers with relatively less content knowledge at the beginning, who gained more content knowledge through the PD had relatively less gains in curriculum-based assessments at the beginning of the PD. This difference, however, diminished as teachers are more exposed to the PD. Similarly, teachers who changed their practice from teacher-centered to student-centered at year-end found their students had relatively less gains at the beginning of the year. This difference also diminished as they were more exposed to the PD.

The surprising finding was that teachers who changed their beliefs about teaching mathematics from discovery/connectionist orientation to transmission orientation found their students had relatively more gains than students taught by other teachers during the third round of assessment. This difference was not statistically significant during the first and second rounds of assessment. This finding is contradictory to our predictions as the PD is designed to help teachers develop more discovery/connectionist orientation of beliefs in teaching. We were expecting more student gains for teachers who changed from transmission orientation to discovery/connectionist orientation. Consistent with this finding was that students taught by teachers who changed their beliefs about mathematics from transmission to discovery/connectionist orientation had relatively less gains than students taught by other teachers.

Comparison of EOG mathematics scores between the treatment group and comparison group at School District B revealed no significant differences, F (1, 914) = 0.002, p = .96, partial η^2 < .001. No gender differences were noticed either, F (1, 914) = 0.04, p = .85, partial η^2 < .001. The only statistically significant difference was between ethnic groups, F (4, 914) = 10.61, p < .001, partial η^2 = .04. Comparison of descriptive statistics of EOG scores between the treatment and comparison groups are presented in Table 3. Post hoc multiple comparison using Tukey HSD method suggested that Caucasian and Asian student outperformed Hispanic and African

American students in both treatment and comparison groups. Repeated measure ANOVA using the baseline data (08-09 EOG) of Grades 4-5 students as pre-test suggested a significant interaction effect between time and grade, F (1, 566) = 166.85, $p < .001$, partial $\eta^2 = .23$. Plots of this interaction revealed that Grade 4 student made significantly more gains than Grade 5 students in comparison to their baseline data (when these students were tested at the end of Grades 3 and Grades 4, respectively).

Along with analyzing teacher and student quantitative measures, qualitative data analysis highlighted themes surrounding teachers' experiences with PD. Those were: teachers as learners, enactment of PD content, teachers as self-evaluators, and the pressure of the state tests.

Teachers as Learners

One important theme that emerged in this data was the teachers' experience as a learner. Throughout the year long study, teachers evolved as learners. Within the context of the teacher as a learner, several subcategories were identified: the teachers' view of mathematics, the teachers' view of teaching mathematics, and the teachers' view of being a mathematics leader.

Teachers' view of mathematics. Teachers reported that the PD influenced their views about mathematics. One third grade teacher stated that:

> This week has really taught me that learning math is all about exploring different ways to use numbers and strategies that can be applied to everyday life. It's not just about getting an answer…there are several ways to get answers and that it's important for children to be creative and analyze numbers as well as discuss and explain their ideas.

During one observation of a fourth grade teacher's classroom, the teacher reiterated that her students often found ways to solve mathematics problems that surprised her. A similar occurrence happened when a student solved a difficult problem using a strategy that the teacher had not thought to use for that type of problem.

Teachers' view of teaching mathematics. One teacher noted in the interview that being a participant in the PD and teaching with *Investigations* allowed her to become able to, "accept that children sometimes derive at their solutions in various ways, not just the way they were taught." Teachers also noted changes in their pedagogical process, like their ability to, "critically examine student work in order to determine whether or not learning is occurring…"

One third grade teacher commented during an observation that she felt challenged by the *Investigations* curriculum in a positive way because she was forced to be a more student-centered teacher. Several teachers also mentioned the use of multiple strategies to solve mathematics problems using *Investigations* and how different this methodology was from how they were taught mathematics. Teachers also felt some challenges with having to learn new ways to teach mathematics because of their need to explain this change to parents. One third grade teacher discussed the implications of this challenge in her classroom during an observation. The graduate research assistant witnessed a student in her classroom struggle with this conflict between how his parents helped with his homework and how his teacher taught him to solve a problem.

Teachers' view of being teacher-leaders. Teachers reported that another important factor in their participation in the PD was learning how to lead at their school. One teacher noted, "The leadership training was also very effective. It made me realize that I had to further market the curriculum to my constituents to increase/ensure total buy-in or implementation fidelity."

Enactment of Professional Development Content into Practice

A third grade teacher noted that the curriculum lessons were a challenge to implement. "I quickly realized that I had to control Workshop sessions until my students had mastered protocols. Then, I gradually loosened the reins and increased students' responsibilities as well as the number of activities that would be completed." This teacher's change in the classroom procedures was noted during the observation. She created a structured system for students to rotate through Math Workshop lessons instead of letting students choose their activity as the *Investigations* curriculum advises.

While some teachers tailored the Math Workshop lessons to their students, others modified the actual lesson content or structure of the entire curriculum unit. This was often observed in the classroom. Common reasons included a lack of time, the need to supplement content to meet state standards, and redundant lessons. One teacher stated:

> Though they [the lessons] are designed to build upon each other, some could have been combined. So, I remedied this dilemma by using some of them as extension activities for my high-fliers or as additional performance tasks (re-teach or remediation) for my struggling students.

One fourth grade teacher commented during an observation that they were "skipping around" the curriculum and not following it in order, based on her pacing guide and student needs.

The *Investigations* curriculum also contains scripted lessons which teachers can follow closely if they wish. This was uncomfortable for some teachers, who mentioned early in the school year that they disliked teaching with scripted lessons. In one second grade classroom, students were just beginning to explore concepts on their own when math time ended and they were forced to switch content areas. In another case, the teacher kept interrupting students as they worked individually in order to insert parts of the scripted lesson that she might have missed. This greatly disturbed the students' progress, as shown by their inability to return to their work quickly.

Teachers as Self-evaluators

Teachers consistently expressed the desire for someone to observe their teaching. Teachers always asked for feedback from the observations. In an email, one participant asked, "… how do these observations help the program as a whole?" Another teacher asked, "How does what you observed be put together so that I may improve or adjust my methods?" Teachers expressed their desire for team-teaching activities and observing other teachers in their responses to the Leadership Log. Some teachers consistently mentioned that they wished they could watch other teachers in their buildings teach with *Investigations*. A first grade teacher stated. "I don't know if I am doing it well or not. I would like to see how they [other teachers] manage the materials in their classrooms."

Overall, practices for helping the teachers become self-evaluators of their own practice were not implemented fully in the first year of the grant project. Although their comfort level with the curriculum increased throughout the year, their need for approval from a curriculum and a pedagogy expert did not change.

Pressure of the State Test

The pressure of the standardized state mathematics assessment was mentioned by most third, fourth and fifth grade teachers. In their eyes, the test conflicted with their teaching of *Investigations* in both format and content. Most teachers in these grades stopped using *Investigations* at least a month before the test in order to focus on test-like questions. Other teachers stopped teaching with *Investigations* prior to the test in order to give students practice on answering multiple choice questions. Overall, although most teachers did believe that *Investigations* helped students learn math, they voiced concerns over the open-ended format used in the curriculum compared to the multiple choice testing format. One teacher stated, "I would like to have more time to dissect the standard course [of study] and especially test items to ensure that my students are able to show all that they can do on state tests."

Development of the Needs Assessment

Following the ETMM design, we collected data from the time of initial adoption and early implementations to assess the needs of the teacher participants. Based upon formal and informal interviews and classroom observations, we developed a needs assessment (Appendix G) that consisted of four open-ended questions and 21 closed-ended questions. The open-ended questions asked teachers to report their expectations from the PD, how they can benefit from the PD, and what the program developers can do to help them implement the PD in their classrooms. The closed-ended questions asked the teachers to rate, on a five-point-Likert scale, to indicate their knowledge in mathematics, comfort level to teach mathematics using the strategies learned at PD, skills to assess student learning in mathematics, and leadership abilities to help other teachers use the curriculum effectively.

Discussion and Significance

Teacher PD has to be relevant to teachers' daily practices, while also addressing student learning (Guskey, 2003; Loucks-Horsley et al., 2009; Wilson & Berne, 1999). The teachers' experiences in the project influenced both their implementation of the new knowledge and skills they acquire. This study provides evidence for how teachers' perceptions of a PD program influence their enactment of PD content in their classroom. Through this PD program, teachers grew in their views of mathematics, teaching of mathematics, leadership skills, and self-reflection capacity. Teachers also expressed their own limitations in being able to evaluate themselves as teachers and how the state test impacts their work.

In terms of reported instructional practices, prior to the project, 40 of 52 teachers (76.92%) were student-centered. By the end of the project, 34 of the 39 teachers (87.19%) reported to use primarily student-centered pedagogies. A majority of the professional development (over 60 of the 84 hours) focused on effective implementation of *Investigations* and related practices, which may explain the shift towards student-centered pedagogies. Prior pedagogical-specific professional development projects have found increases in teachers’ practices within the first year (Garet et al., 2001; Heck et al., 2008; Penuel et al., 2007).

The results were more mixed with teacher beliefs, as teachers remained constant, become more transmission (teacher-centered) or more connectionist/discovery (student-centered). Our supplementary qualitative data references a lot of teacher apprehension about whether these pedagogies will lead to student achievement. Previous studies noted that in some cases teachers required many years to work on shifting their instructional practices before shifting their beliefs (Fennema et al., 1996; Penuel et al., 2007). In this project, teachers definitely seemed more willing to shift their instructional practices by using *Investigations* before their beliefs. Again, the project’s focus on instructional practices might be a possible cause for this finding.

Gains in student learning outcomes had statistically significant links to some teacher-level variables. Teachers who shifted from teacher- to student-centered practices had higher student learning outcomes on the first assessment than their peers. This supports work from prior studies that linked student-centered pedagogies with student learning outcomes (Stigler & Hiebert, 1999). In regards to beliefs, results were mixed; students whose teachers shifted towards transmission views of mathematics teaching outscored peers whose teachers were discovery/connectionist. However, on the second assessment, students whose teachers had shifted from transmission to discovery/connectionist in regards to mathematics learning and mathematics as a subject area outperformed their peers. Carpenter et al. (1996) found that teachers who had embraced both student-centered beliefs and practices saw gains in student learning outcomes on problem solving measures.

As standards-based curriculum is significantly different from traditional didactic approaches (Smith & Smith, 2006), teachers need substantial support in the form of in-class assistance in additional to PD workshops. This study revealed that the in-class assistance provided to teacher participants during the first year of the three-year grant is insufficient. As a response to teacher's request, teacher leaders were recruited from the first year teacher participants. These teacher leaders will be trained to facilitate second year teacher participants to implement the standards-based curriculum in the classroom through modeling, observation, co-teaching, posing high-level questions, facilitating discussions in which students can share strategies, sharing teaching materials and classroom activities, etc. This implies to other PD programs that sufficient on-site support should be considered at the beginning of the PD to enhance the fidelity of implementation.

Another finding from this study is that teacher beliefs measured by TBQ are not stable. Previous studies indicated that teachers required many years to work on shifting their instructional practices before shifting their beliefs (Fennema et al., 1996; Penuel, Fishman, Yamaguchi, & Gallagher, 2007). Most of the teacher participants' beliefs stayed the same; however, nearly one-third of the teachers changed their beliefs about teaching or learning mathematics from discovery/connectionist orientation to transmission orientation or vice versa. This change was surprising and was not aligned with the literature with respect to the connection between teacher beliefs and student academic achievement either (Carpenter, Fennema, & Franke, 1996; Stigler & Hiebert, 1999). Therefore, we question the validity of TBQ and are looking for another measure of teacher beliefs. We are also trying alternative methods to code teacher beliefs using TBQ to see if it was our coding method that was causing this unexpected outcome. The surprising finding that teachers who changed their beliefs from discovery/connectionist orientation to transmission orientation found their students had relatively more gains than students taught by other teachers during the third round of assessment could be explained by the pressure of the standardized state mathematics assessment. In teacher's eyes, the test conflicted with their teaching of *Investigations* in both format and content. Most teachers in these grades stopped using *Investigations* at least a month before the test in order to focus on test-like questions. Other teachers stopped teaching with *Investigations* prior to the test in order to give students practice on answering multiple choice questions. Overall, although most teachers did believe that *Investigations* helped students learn math, they voiced concerns over the open-ended format used in the curriculum compared to the multiple choice testing format.

Subsequent studies from this project will examine how teacher's experiences in PD translate specific pedagogies in their classrooms, and the impacts on their students' learning. For future studies, there is a need to reconsider the scoring of the assessments. For the purposes of this study, the researchers scored the assessments numerically, assigning scores to student answers based on teacher-developed rubrics, and the converting scores to percentages. It is possible that the scoring of the assessments does not properly assess the level of student growth in mathematics achievement.

Table 1

Descriptive Statistics of Student Assessment Gain Scores

	Minimum	Maximum	*M*	*SD*
First Round (*n* = 629)	-83.33	100	18.74	30.59
Second Round (*n* = 542)	-44.44	100	22.40	31.51
Third Round (*n* = 450)	-44.44	100	25.25	30.30

Table 2

Parameter Estimates of Two-Level Hierarchical Liner Models

	First Round		Second Round		Third Round	
	Coef.	s.e.	Coef.	s.e.	Coef.	s.e.
Knowledge	-1.53	0.57*	-0.38	0.45	0.55	0.66
Belief in						
Teaching						
DC to T	-10.31	7.91	3.20	7.43	24.31	4.95***
T to DC	-1.33	7.78	5.93	8.09	19.10	10.53
Learning						
DC to T	-6.00	6.34	2.52	9.17	-17.80	13.54
T to DC	1.89	6.71	-14.77	6.77*	-6.81	19.80
Mathematics						
DC to T	-8.44	7.03	17.48	10.97	-14.88	9.57
T to DC	5.37	6.01	-13.12	3.62**	-34.06	19.48
Teacher Practice						
T to S	-10.90	4.72*	-4.55	6.14	4.07	9.78
T to T	9.15	13.99	-9.07	5.71	4.30	8.50
T to S vs. T to T	-20.08	13.37	4.36	5.77	-0.44	9.66

Note. (a) **p* < .05; ** *p* < .01; ***p* < .001. (b) DC to T means teacher beliefs changed from discovery/connectionist orientation to transmission orientation; T to DC means teacher beliefs changed from transmission orientation to discovery/connectionist orientation; the comparison group was teachers whose did not report a change of their beliefs. (c) T to S means that teacher practice changed from teacher-centered to student-centered; T to T means that teacher practice stayed as teacher-centered; the comparison group was teachers whose practice stayed as student-centered. (d) T to S vs. T to T means a comparison between teachers whose practice changed from teacher-centered to student-centered versus teachers whose practice stayed as teacher-centered.

Table 3

Comparison of EOG scores between Treatment and Comparison Groups in School District B

		Treatment Group 09-10 Test		Comparison Group 09-10 Test	
		M	*SD*	*M*	*SD*
Ethnicity	Caucasian	356.12	8.91	354.20	8.28
	Hispanic	351.71	7.88	350.95	7.48
	African American	351.03	7.41	348.67	8.21
	Multi-Racial	352.57	5.00	349.13	6.45
	Asian	356.67	3.22	361.00	12.96
Gender	Female	354.73	6.37	351.67	8.02
	Male	352.73	9.77	351.71	8.70

Table 4

Comparison of EOG scores in School District B to baseline data.

		Treatment Group				Comparison Group			
		08-09 Test		09-10 Test		08-09 Test		09-10 Test	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Grade	Grade 4	342.73	6.94	352.41	8.09	342.72	7.82	351.04	8.24
	Grade 5	351.03	8.16	354.06	8.32	349.65	8.15	352.28	8.44

Note: The grade listed is according to student status in the academic year 2009-2010.

Appendix A: Teacher Beliefs Questionnaire

Teacher name: ________________________ Grade(s) taught: ________

Indicate the degree to which you agree with each statement below by giving each statement a percentage so that the sum of the three percentages in each section is 100.

A. Mathematics is: Percents

1. A given body of knowledge and standard procedures; a set of universal truths and rules which need to be conveyed to students: _____

2. A creative subject in which the teacher should take a facilitating role, allowing students to create their own concepts and methods: _____

3. An interconnected body of ideas which the teacher and the student create together through discussion: _____

B. Learning is: Percents

1. An individual activity based on watching, listening and imitating until fluency is attained: ______

2. An individual activity based on practical exploration and reflection: ______

3. An interpersonal activity in which students are challenged and arrive at understanding through discussion: ______

C. Teaching is: Percents

1. Structuring a linear curriculum for the students; giving verbal explanations and checking that these have been understood through practice questions; correcting misunderstandings when students fail to grasp what is taught: ______

2. Assessing when a student is ready to learn; providing a stimulating environment to facilitate exploration; avoiding misunderstandings by the careful sequencing of experiences: ______

3. A non-linear dialogue between teacher and students in which meanings and connections are explored verbally where misunderstandings are made explicit and worked on: ______

This questionnaire was adapted from Swan, M. (2007). Designing and using research instruments to describe the beliefs and practices of mathematics teachers. *Research in Education, 75*, 58-70. Permit for use was obtained on May 29, 2009.

Appendix B: Teacher Practices Questionnaire

Name: ____

Indicate the frequency with which you utilize each of the following practices in your teaching by **circling** the number that corresponds with your response.

	Practice	Almost Never	Sometimes	Half the time	Most of the time	Almost Always
1.	Students learn through doing exercises.	0	1	2	3	4
2.	Students work on their own, consulting a neighbor from time to time.	0	1	2	3	4
3.	Students use only the methods I teach them.	0	1	2	3	4
4.	Students start with easy questions and work up to harder questions.	0	1	2	3	4
5.	Students choose which questions they tackle.	0	1	2	3	4
6.	I encourage students to work more slowly.	0	1	2	3	4
7.	Students compare different methods for doing questions.	0	1	2	3	4
8.	I teach each topic from the beginning, assuming they don’t have any prior knowledge of the topic.	0	1	2	3	4
9.	I teach the whole class at once.	0	1	2	3	4
10.	I try to cover everything in a topic.	0	1	2	3	4
11.	I draw links between topics and move back and forth between topics.	0	1	2	3	4
12.	I am surprised by the ideas that come up in a lesson.	0	1	2	3	4
13.	I avoid students making mistakes by explaining things carefully first.	0	1	2	3	4
14.	I tend to follow the textbook or worksheets closely.	0	1	2	3	4
15.	Students learn through discussing their ideas.	0	1	2	3	4
16.	Students work collaboratively in pairs or small groups.	0	1	2	3	4
17.	Students invent their own methods.	0	1	2	3	4
18.	I tell students which questions to tackle.	0	1	2	3	4
19.	I only go through one method for doing each question.	0	1	2	3	4
20.	I find out which parts students already understand and don’t teach those parts.	0	1	2	3	4
21.	I teach each student differently according to individual needs.	0	1	2	3	4
22.	I tend to teach each topic separately.	0	1	2	3	4
23.	I know exactly which topics each lesson will contain.	0	1	2	3	4
24.	I encourage students to make and discuss mistakes.	0	1	2	3	4
25.	I jump between topics as the need arises.	0	1	2	3	4

This questionnaire was adapted from Swan, M. (2007). Designing and using research instruments to describe the beliefs and practices of mathematics teachers. *Research in Education, 75*, 58-70. Permit for use was obtained on May 29, 2009.

Appendix C: Sample of Content Knowledge for Teaching Mathematics (CKT-M)

Ms. Dominguez was working with a new textbook and she noticed that it gave more attention to the number 0 than her old book. She came across a page that asked students to determine if a few statements about 0 were true or false. Intrigued, she showed them to her sister who is also a teacher, and asked her what she thought.

Which statement(s) should the sisters select as being true? (Mark YES, NO, or I'M NOT SURE for each item below.)

	Yes	No	I'm not sure
a) 0 is an even number.	1	2	3
b) 0 is not really a number. It is a placeholder in writing big numbers.	1	2	3
c) The number 8 can be written as 008.	1	2	3

Appendix D: Observation Questions

Observation Instrument

Teacher: ______________________ Date of Observation: ___________________

School: ________________________ Textbook/Module: _____________________

Grade: __________________ Chapter/Unit/pages: ____________________

Pre-Observation Questions

1. What is the main topic of the lesson?
2. What are the primary learning goals or objectives in this lesson?
3. Where is the lesson situated within the unit? How will the present lesson connect to previous or subsequent lessons? What do you assume your students already know?
4. Do you anticipate any potential difficulties in delivering the lesson? If so, how do you plan to handle them if they arise?
5. Do you anticipate any difficulties the students will have with the mathematics in the lesson?
6. Have you taught this lesson before?

Post-Observation Questions

1. Looking back, what made you decide to choose the particular examples/problems you used?
2. Now that you have taught the lesson, please reflect on the effectiveness of using these examples/problems in this lesson?
3. For this lesson, the main goal you had for your students was: ________________ (see question 2 of the pre-observation interview). Do you think your students reached the goal?

Appendix E: Interview Protocol

Evaluation of Professional Development for the CoDE: I project, an MSP Grant project

Interview Protocol for Participants

1. What were your needs for professional development to implement the *Investigations* curriculum before last summer (2009)?
2. What were your expectations of the professional development sessions? Did they meet your needs?
3. Of the professional development you've received this year, which session(s) were most helpful to you?
    - Summer 2009, 10 days (Overview of Investigations & Math Content)
    - September 2009
    - November 2009
    - February 2010
    - April 2010
4. How have you benefited by participating in these professional development sessions?
5. Do you think that Investigations have any impact on your teaching methods or the student learning process? If so, how do you think your teaching methods or your students been impacted by Investigations?
6. What barriers have you encountered when implementing *Investigations*?
7. How have you (your practice or philosophy) been impacted by participating in this grant?
8. What needs do you have for future professional development for this grant?
9. What else do you need to keep working with *Investigations?*
10. What suggestions would you provide for professional development for next year's cohort?

Appendix F: Leadership Log

Please evaluate the frequency and impact of each of the activities that are listed by placing a check mark for the appropriate statement under "frequency" and "impact."

	Frequency					**Impact**			
	Very often (at least once a week)	Sometimes (once or twice a month)	Very seldom (a few times a year)	Never		Very helpful	Somewhat helpful	Seldom helpful	Not helpful
1. Facilitating collaborative planning with other teachers									
2. Teaching a model lesson while other teachers watch.									
3. Co-teaching a lesson with another teacher.									
4. Collaboratively examining student work.									
5. Observing a colleague's teaching and providing feedback.									
6. Facilitating a workshop about Investigations.									

Please use this space to elaborate on any leadership experiences mentioned above.

References

Ball, D. L., Lubienski, S. T., & Mewborn, D. S. (2001). Research on teaching mathematics: The unsolved problem of teachers' mathematical knowledge. In V. Richardson (Ed.), *Handbook of research on teaching* (4th ed.) (433-456). Washington, DC: American Educational Research Association.

Blank, R.K., & de Las Alas, N. (2009). Effects of teacher professional development on gains in student achievement. Washington, D.C.: Council of Chief State School Officers. Retrieved June 29, 2010 from: http://www.compadre.org/ptec/items/detail. cfm?id=9245

Bogdan, R. C., & Biklen, S. K. (1998). *Qualitative research for education: An introduction to theory and methods*. Boston, MA: Allyn & Bacon.

Borko, H. (2004). Professional development and teacher learning: Mapping the terrain. *Educational Researcher*, *33*(8), 3-15.

Carpenter, T. P., Fennema, E., & Franke, M. L. (1996). Cognitively Guided Instruction: A knowledge base for reform in primary mathematics instruction. *The Elementary School Journal, 97*(1), 3-20.

Century, J., Rudnick, M., & Freeman, C. (2010). A framework for measuring fidelity of implementation: A foundation for shared language and accumulation of knowledge. *American Journal of Evaluation, 31*, 199-218.

Chatterji, M. (2004). Evidence on "what works": An argument for extended-term mixed-method (ETMM) evaluation designs. *Educational Researcher*, *33*(9), 3-13.

Cohen, S. (2005). Teachers' professional development and the elementary mathematics classroom: Bringing understandings to light. Mahwaw, NJ: Lawrence Earlbaum Associates, Inc.

Crotty, M. (1998). The foundations of social research. London: Sage.

Dane, A. V., & Schneider, B. H. (1998). Program integrity in primary and early secondary prevention: Are implementation effects out of control? *Clinical Psychology Review, 18,* 23-45.

Darling-Hammond, L., Wei, R.C., Andree, A., Richardson, N., & Orphanos, S. (2009). Professional learning in the learning profession: A status report on teacher professional development in the United States and abroad. Washington, D.C.: National Staff Development Council.

Desimone, L. M., Porter, A. C., Garet, M. S., Yoon, K. S., & Birman, B. F. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis, 24*(3), 81-112.

Eisenhart, M., & Towne, L. (2003). Contestation and change in national poicy on "scientifically-based" education research. *Educational Researcher, 32*(7), 31-38.

Fennema, L., Carpenter, T., Franke, M., Levi, M., Jacobs, V., & Empson, S. (1996). A longitudinal study of learning to use children's thinking in mathematics instruction. *Journal for Research in Mathematics Education, 27*(4), 403-434.

Fitzpatrick, J. L., Sanders, J. R., & Worthen, B. R. (2004). *Program evaluation: Alternative approaches and practical guidelines.* Boston: Pearson.

Garet, M., Porter, A., Desimone, L., Briman, B., & Yoon, K. (2001). What makes professional development effective? Analysis of a national sample of teachers. *American Educational Research Journal, 38*(4), 915-945.

Glesne, C. (2011). *Becoming qualitative researchers.* Boston. Pearson.

Guskey, T. R. (2003). What makes professional development effective? *Phi Delta Kappan*, *84*(10), 748-750.

Hall, G. E., & Hord, S. M. (1987). *Change in schools: Facilitating the process.* State University of New York Press.

Heck, D.J., Banilower, E.R., Weiss, I.R., & Rosenberg, S.L. (2008). Studying the effects of professional development: The case of the NSF's local systemic change through teacher enhancement initiative. *Journal for Research in Mathematics Education, 39*(2), 113-152.

Henry, G. T., & Mark, M. M. (2003). Beyond use: Understanding evaluation's influence on attitudes and actions. *American Journal of Evaluation, 24*, 293-314.

Hill, H.C., Rowan, B., & Ball, D. (2005). Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal*, *42* (2), 371-406.

Loucks-Horsley, S., Love, N., Stiles, K. E., Mundry, S. & Hewson, P. W. (2009). *Designing professional development for teachers of science and mathematics (3rd ed.)*. Thousand Oaks, CA: Corwin Press.

Lynch, S., & O'Donnell, C. (2005). *The evolving definition, measurement, and conceptualization of fidelity of implementation in scale-up of highly rated science curriculum units in diverse middle schools.* Paper presented at the Annual Meeting of the American Educational Research Association, Montreal, Canada.

Mokros, J. (2003). Learning to reason numerically: The impact of Investigations. In S. Senk & D. Thompson (Eds.), *Standards-Based School Mathematics Curricula: What Are They? What Do Students Learn? (*pp. 109-131). Mahwah, NJ: Lawrence Erlbaum Associates.

Mowbray, C. T., Holter, M. C., Teague, G. B., & Bybee, D. (2003). Fidelity criteria: Development, measurement, and validation. *The American Journal of Evaluation, 24,* 315-340.

National Partnership for Excellence and Accountability in Teaching (NPEAT) (2000). Revisioning professional development: What learner-centered professional development looks like. Oxford, OH: Author. Retrieved September 10, 2003, from http://www.nsdc.org/library/policy/npeat213.pdf

Penuel, W., Fishman, B., Yamaguchi, R., & Gallagher, L. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal, 44* (4), 921-958.

Remillard, J. T. (2005). Examining key concepts in research on teachers' use of mathematics curricula. *Review of Educational Research, 75*(2), 211-246.

Rossi, P. H., Freeman, H. E., & Lipsey, M. W. (1999). *Evaluation: A systematic approach.* Thousand Oaks, CA: Sage.

Ruiz-Primo, M. A. (2005). *A multi-method and multi-source approach for studying fidelity of implementation.* Paper presented at the Annual Meeting of the American Educational Research Association, Montreal, Canada.

Russell, S.J., Economopolous, K., et al. (2007). *Investigations in Number, Data, and Space* (2nd ed.). Glenview: Pearson Scott Foresman.

Shadish, W. R., Cook, T. D., & Campbell, D. T. (2002). *Experimental and quasi-experimental designs for generalized causal inference.* Boston, MA: Houghton Mifflin Co.

Smith, S. Z., & Smith, M. E. (2006). Assessing elementary understanding of multiplication concepts. *School Science and Mathematics, 106*(3), 140-149.

Stein, M.K. and Kim, G. (2008). The role of mathematics curriculum materials in large-scale urban reform: An analysis of demands and opportunities for teacher learning. In J.

Remillard (Ed.), Teachers' use of mathematics curriculum materials: Research perspectives on relationships between teachers and curriculum. New York: Routledge.

Stigler, J., & Hiebert, J., (1999). *The teaching gap*. New York: The Free Press.

Supovitz, J. A. (2003). Evidence of the influence of the National Science Education Standards on the professional development system. In K. S. Hollweg & D. Hill (Eds.), *What is the influence of the National Science Standards?* (pp. 64–75). Washington, DC: National Academy Press.

Swan, M. (2007). Designing and using research instruments to describe the beliefs and practices of mathematics teachers. *Research in Education, 75*, 58-70.

Wang, M. C., Nojan, M., Strom, C. D., & Walberg, H. J. (1984). The utility of degree of implementation measures in program implementation and evaluation research. *Curriculum Inquiry, 14,* 249-286.

Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. *Review of Research in Education, 24,* 173–209.

Yoon, K. S., Duncan, T., Lee, S. W.-Y., Scarloss, B., & Shapley, K. (2007). *Reviewing the evidence on how teacher professional development affects student achievement* (Issues & Answers Report, REL 2007–No. 033). Washington, DC: U.S. Department of Education, Institute of Education Sciences, National Center for Education Evaluation and Regional Assistance, Regional Educational Laboratory Southwest. Retrieved December 31, 2008, from: http://ies.ed.gov/ncee/edlabs.