Supporting Teachers' Enactment of Elementary School Student-Centered Mathematics Pedagogies: The Evaluation of a Curriculum-Focused Professional Development Program

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Abstract

This paper shares the findings from the evaluation of a year-long implementation of a Mathematics Science Partnership (MSP) professional development project, *Content Development* for *Investigations* (CoDE:I), designed to support elementary school teachers' enactment of standards-based mathematics pedagogies. Teachers participated in a 48 hour summer institute followed by 24 hours of follow-up work during the school year. Statistical analyses of teacher-participants' content knowledge, beliefs, practices and their students' achievement on curriculum-based measures indicated positive gains in teachers' mathematical content knowledge, their instructional practices, and in some cases students' achievement on curriculum-based assessments. Implications for future research and the design of professional development are also shared.

Keywords: professional development, Standards-based instruction, teacher beliefs, instructional practices

Overview

Student-Centered Mathematics Pedagogies

Mathematics educators have advocated for the enactment of student-centered mathematics pedagogies in order to increase both student achievement and students' understanding of mathematics concepts (Higgins & Parsons, 2010; Stigler & Hiebert, 1999; U.S. Department of Education, 2008). Despite mixed results in empirical studies, analyses of international studies have noted that teachers in countries that perform well on international assessments have a deep understanding of mathematics and pose rich mathematical tasks (Stigler & Hiebert, 1999). In this paper, we use the term student-centered pedagogies to include instructional practices that align with the National Council for Teachers of Mathematics (NCTM) *Principles and Standards*. Specifically, these pedagogies include: posing cognitively demanding mathematical tasks (Henningsen & Stein, 1997), asking questions to examine students' mathematical thinking (Carpenter, Fennema, & Franke, 1996), providing opportunities for students to engage in discourse about tasks and mathematical ideas (Huffered-Ackles, Fuson, & Sherin, 2004), and using formative data to design subsequent mathematical tasks (Joyner & Muri, 2010).

While the enactment of student-centered pedagogies has been empirically linked to gains in student learning (Carpenter et al., 1996; Heck, Banilower, Weiss, & Rosenberg, 2008; Polly,

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2008), prior studies have noted teachers' struggles implementing these types of instructional practices with a high level of fidelity (Boston & Smith, 2009, 2011; Cognition and Technology Group at Vanderbilt, 1997; Henningsen & Stein, 1997; Poly & Hannafin, 2011). To this end, professional development programs have been held up as a possible way to support teachers' enactment of student-centered pedagogies (Polly & Hannafin, 2011; U.S. Department of Education, 2008).

Theoretical Framework: Learner-Centered Professional Development (LCPD)

This study is grounded in learner-centered professional development (LCPD), an empirically-based construct that is rooted in constructivist epistemologies (Polly & Hannafin, 2011). The American Psychological Association's research-based learner-centered principles (Alexander & Murphy, 1998; APA Work Group, 1997; Orrill, 2001) represent a synthesis of research on teaching and learning, which have been adapted for teacher learning (National Partnership for Excellence and Accountability in Testing [NPEAT], 2000; Polly & Hannafin, 2011). Polly and Hannafin (2011) mapped the learner-centered principles to research on professional development, identifying the following characteristics of learner-centered professional development programs:

- addressing student learning deficits (Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2009);
- providing teachers with ownership of professional development activities (NPEAT, 2000);
- promoting collaboration (Desimone, Porter, Garet, Yoon, & Birman, 2002);
- simultaneously developing teachers' pedagogical and content knowledge (Garet, Porter, Desimone, Birman, & Yoon, 2001);
- supporting reflection and connections to teachers' practices (Heck et al., 2008); and
- providing ongoing support (e.g. Polly & Hannafin, 2011; Loucks-Horsley et al., 2009).

Professional Development, Teacher Characteristics and Student Learning Outcomes

Effective professional development 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). Further, a large-scale meta-analysis also linked professional development to student learning gains (Yoon, Duncan, Lee, Scarloss & Shapley, 2007).

Teacher beliefs towards mathematics teaching have been associated with teachers' instructional practices (Fennema et al., 1996), use of curricula (Stein & Kim, 2008), and willingness to enact student-centered pedagogies (Heck et al., 2008; Polly & Hannafin, 2011). Teachers' use of student-centered pedagogies has been found to significantly increase student achievement and students' conceptual understanding (Carpenter et al., 1996; Stigler & Hiebert, 1999). Further, studies have found that students whose teachers have deeper content knowledge related to the mathematics that they teach outperform their peers (Hill, Rowan & Ball, 2005).

Research Questions

This study was framed by the following research questions:

- To what extent does professional development influence participants' beliefs about mathematics teaching and learning?
- To what extent does professional development influence participants' reported instructional practices?

- To what extent does professional development influence student learning outcomes on curriculum-based assessments?

Method

Context

The purpose of the MSP project was to develop teachers' knowledge of mathematics content as well as pedagogies related to teaching with the *Standards*-based mathematics curriculum, *Investigations in Number, Data, and Space* (*Investigations*). The participants teach in two school systems located in and near a large city in the southeastern United States. System One is a large, urban school system, and System Two is a smaller suburban school system in a neighboring city. The two school systems conducted professional development separately, but the overall content and focus of the professional development remained consistent. Project staff oversaw the project and worked with both districts. The focus of this paper is to examine the impacts of the project on various teacher characteristics and student learning outcomes only for Year Two of the project.

Professional development activities. During the 48-hour professional development summer workshops teacher-participants completed a variety of activities, including exploring cognitively-demanding mathematical tasks, examining the mathematics standards that their students were expected to learn, and analyzing the activities in the *Investigations* curricula in light of the mathematics standards. Teachers completed a number of the tasks and games in *Investigations* and worked with other participants to devise ways to modify them to decrease or increase the difficulty of the activities as well as to consider how they would formatively assess students' progress.

At various points spread out throughout the entire school year, teacher-participants completed a variety of professional learning activities in their classrooms and school buildings. These activities totaled 24 hours of learning experiences. First, each teacher video recorded a 10 minute discussion that he/she facilitated with the students about a mathematical task or concept. Teachers also facilitated a team planning meeting with their colleagues, in which they led other educators through an analysis of the resources and tasks in *Investigations*. Lastly, teachers had to assess data and formulate a plan for modifying their instruction to meet the various mathematical needs of their students.

Participants

Of the 185 participants, 155 were from System One and 30 from System Two. In System One, participants' years of teaching experience ranged from 1 to 32 years, with the mode being 3 years (n = 14). In System Two, the participants' years of teaching experiences ranged from 1 to 35 years with the mode also being 3 years (n = 5). Participants were also asked to indicate their content certification area, beyond general education. In System One, 64 (41.3%) indicated that they were certified in mathematics. This information was missing for 45 teachers in System One, meaning that they did not specify having or not having math certification. In System Two, 14 (46.7%) indicated they were certified in math. Data were missing for five teachers in System Two, meaning that they did not specify having or not having math certification.

Participants also included 5,070 students, of which 4,184 (82.5%) were from System One and 886 (17.5%) were from System Two. Student demographic information is in Table 1. Also, 4,658 students (91.9%) were students of teacher participants only in Year Two, and 412 (8.1%)

were students of professional development teacher-leaders, who were teacher participants in Year One.

Table 1
Student Demographic Information

		District One	District Two
Grade	K	415 (9.9%)	224 (25.3%)
	1st	642 (15.4%)	100 (11.3%)
	2nd	599 (14.3%)	117 (19.3%)
	3rd	694 (16.6%)	163 (18.4%)
	4th	881 (21.1%)	159 (17.9%)
	5th	951 (22.7%)	69 (7.8%)
Ethnicity	European American	981 (36.2%)	207 (39.8%)
	African American	1066 (39.3%)	140 (26.9%)
	Hispanic	453 (16.7%)	132 (25.4%)
	Asian	119 (4.4%)	4 (0.8%)
	Native American	3 (0.1%)	0 (0%)
	Unspecified/Other	89 (3.3%)	37 (7.1%)
Female		1293 (51.2%)	271 (52.0%)
Male		1234 (48.8%)	250 (48.0%)
Limited English Proficiency		316 (12.5%)	130 (25.0%)
Individualized Educational Plan		157 (6.2%)	77 (14.8%)

Data Collection Methods

Multiple instruments were used to collect data throughout the year. Teacher beliefs, practices and mathematics content knowledge were measured using pre and post test instruments. Student achievement was measured using end of unit assessments from *Investigations* given before and after 3 specific curriculum units 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 degree to which their views aligned with the transmission, discovery, and connectionist views. The sum of the three percentages for each dimension was 100. Teachers were coded as discovery/connectionist if they indicated at least 45% in either discovery or connectionist (Swan, 2007). The TPQ examined each participant's self-report about instructional practices related to their mathematics teaching (Swan, 2007). Each of the items reflected either student-centered or teacher-centered pedagogies. Teachers identified their instructional practices on a 5-point Likert scale, where 0 represented “none of the time” and 4 represented “all of the time.” Following the same procedure as Swan (2007), a practice scale was constructed by reverse coding student-centered statements (items 5, 6, 7, 11, 12, 15, 16, 17, 20, 21, 24, and 25) and averaging the ratings obtained. The Cronbach’s alpha reliability coefficient of these 25 items was .79 (Swan, 2007). 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.” The Content Knowledge for Teaching Test (see sample in Appendix C) measured teachers’ knowledge of mathematics content and knowledge of students and content (Hill et al., 2005). For each teacher, the number of correct items was recorded.

Student achievement measures. The student achievement measures were end-of-unit assessments from the *Investigations* curriculum (Russell et al., 2007). Three units, which were most closely associated with the professional development, were assessed from each grade level. 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). The first assessment was administered within the first two months of the school year. The second assessment was administered during the middle (months 5 or 6 of the year), while the third assessment was administered sometime during the last two months of the school year. Each assessment was converted to a percentage. Both original scores and gain scores were used in the analyses.

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) was used to analyze the student data nested within teacher variables to account for the within- and between-group variances.

Results

Influence on Teacher Beliefs

In System One, 122 teachers completed the TBQ at both the beginning and the end of Year Two. Of these teachers, 27 (22.1%) changed from a transmission to a discovery/ connectionist orientation, 73 (59.8%) remained unchanged, and 22 (18.0%) changed from a discovery/connectionist to a transmission orientation with respect to teacher beliefs about mathematics. As for teacher beliefs about learning mathematics, 18 (14.8%) changed from a transmission to a discovery/connectionist orientation, 83 (68.0%) remained unchanged, and 21 (17.2%) changed from a discovery/connectionist to a transmission orientation. Finally, 27 (22.1%) changed from a transmission to discovery/connectionist orientation, 74 (60.7%) remained unchanged, and 21 (17.2%) changed from a discovery/connectionist to transmission orientation with respect to teacher beliefs about teaching mathematics.

In System Two, 25 teachers completed the TBQ at both the beginning and the end of Year Two. Of these teachers, 8 (32.0%) changed from a transmission to a discovery/connectionist orientation, 14 (56.0%) remained unchanged, and 3 (12.0%) changed from a discovery/connectionist to a transmission orientation with respect to teacher beliefs about mathematics. As for teacher beliefs about learning mathematics, 3 (12.0%) changed from a transmission to a discovery/connectionist orientation, 16 (64.0%) remained unchanged, and 6 (24.0%) changed from a discovery/connectionist to a transmission orientation. Finally, 2 (8.0%)

changed from a transmission to a discovery/connectionist orientation, 15 (60.0%) remained unchanged, and 8 (32.0%) changed from a discovery/connectionist to a transmission orientation with respect to teacher beliefs about teaching mathematics.

Influence on Teacher Practices

In System One, 124 teachers completed the TPQ at the beginning and end of Year Two. Of these teachers, 1 (0.8%) changed from student-centered to teacher-centered, 55 (44.4%) remained unchanged, and 68 (54.8%) changed from teacher-centered to student-centered with respect to their practices in the classroom, indicating a significant impact of the PD on teacher's practices. In System Two, 28 teachers completed the TPQ at the beginning and end of Year Two. Of these teachers, 2 (7.1%) changed from student-centered to teacher-centered, 10 (35.7%) remained unchanged, and 16 (57.1%) changed from teacher-centered to student-centered with respect to their practices in the classroom, also indicating a significant impact of the PD on teacher's practices.

Influence on Mathematical Content Knowledge for Teaching

The Content Knowledge Test was completed by 114 teachers in System One and 25 teachers in System two at the beginning and end of the year. Descriptive statistics for teacher content knowledge are presented in Table 2.

Table 2
Descriptive Statistics of Teacher Content Knowledge in Mathematics

		Pre	Post	Gain
System One (*n* = 114)	*M*	33.49	35.81	2.32
	SD	8.43	9.57	5.37
System Two (*n* = 25)	*M*	33.16	34.84	1.68
	SD	6.86	6.27	6.32

Repeated measures analysis of variance revealed no statistically significant interaction effect between school system and time, $F(1, 137) = 0.27$, $p = .61$, partial $\eta^2 = .002$, indicating that teachers in the two school systems did not differ with respect to the change in their content knowledge in mathematics from the beginning to the end of the year. The main effect of change, however, was statistically significant, $F(1, 137) = 10.64$, $p = .001$, partial $\eta^2 = .07$, indicating that teachers in both school systems experienced significant gain in their content knowledge after participating in the PD. Gain scores were completed by subtracting pre-test scores from post-test scores (Table 2). The large standard deviations of the gain scores suggested that the impact of the PD on teacher's content knowledge varied, with some teachers experiencing large gains, some experiencing lesser gains, and some experiencing negative gains. In summary, these results suggest that the PD was successful in increasing teacher's content knowledge in teaching mathematics in general.

Influence on Student Learning Outcomes

Student assessment including gain scores (post-test minus pre-test) are presented in Table 3. Kindergarten students were analyzed separately from students in grades 1-5 because the measure of student learning outcomes was the same for the Kindergarten students for all three rounds of assessments but was different each round for students in grades 1-5.

Table 3
Descriptive Statistics of Student Assessment in Mathematics

			First Round			Second Round			Third Round		
			n	*M*	*SD*	*n*	*M*	*SD*	*n*	*M*	*SD*
System One	Kindergarten		371	87.96	24.42	178	94.57	19.77	233	95.85	16.29
	Grades 1-5	Pretest	3008	51.03	33.73	2937	30.84	29.99	2926	20.65	24.69
		Posttest	2358	80.03	26.24	2308	74.04	28.95	2039	66.10	31.29
		Gain	2044	28.60	35.88	1896	41.25	34.08	1614	45.35	34.83
System Two	Kindergarten		195	78.55	31.11	157	92.36	19.92	165	96.16	13.35
	Grades 1-5	Pretest	379	43.11	34.73	472	38.24	31.67	322	31.03	32.51
		Posttest	386	72.33	28.20	372	73.43	29.01	308	68.00	32.04
		Gain	255	34.43	36.67	299	35.92	36.11	248	35.21	34.32

Note. Kindergarten students were assessed on the same content three times during the year whereas students in grades 1-5 were assessed (pretest and posttest) on three different content areas.

Multivariate analysis of variance (MANOVA) noted statistically significant differences between the two school systems on the combination of all kindergarten student assessments, $F(3, 249) = 3.38$, $p = .02$, partial $\eta^2 = .04$. Tests of between-subjects effects showed that the students in the two school systems were statistically significantly different in the assessment during Round One, $F(1, 251) = 9.46$, $p = .002$, partial $\eta^2 = .04$, but not during Round Two, $F(1, 251) = 0.65$, $p = .42$, partial $\eta^2 = .003$, or Round Three, $F(1, 251) = 0.01$, $p = .94$, partial $\eta^2 < .001$. As for students in grades 1-5, MANOVA also noted statistically significant differences between the two school systems on the combination of all student assessments, $F(6, 1222) = 15.40$, $p < .001$, partial $\eta^2 = .07$. Tests of between-subjects effects showed that the students in the two school systems were statistically significantly different on the pretest, $F(1, 1227) = 31.48$, $p < .001$, partial $\eta^2 = .03$, and posttest, $F(1, 1227) = 16.21$, $p < .001$, partial $\eta^2 = .01$, during Round One. No statistically significant differences, however, were noticed between the two school systems during Round Two for either the pretest, $F(1, 1227) = 0.02$, $p = .90$, partial $\eta^2 < .001$, or the posttest, $F(1, 1227) = 2.31$, $p = .13$, partial $\eta^2 = .002$. During Round Three, statistically significant differences were found between the two school systems for the pretest, $F(1, 1227) = 18.79$, $p < .001$, partial $\eta^2 = .02$, but not for the posttest, $F(1, 1227) = 0.48$, $p = .49$, partial $\eta^2 < .001$. With respect to the gain scores, statistically significantly differences were noticed between the two school systems during Round One, $F(1, 1227) = 7.45$, $p = .01$, partial $\eta^2 = .01$, and during Round Three, $F(1, 1227) = 6.84$, $p = .01$, partial $\eta^2 = .01$, but not during Round Two, $F(1, 1227) = 1.30$, $p = .25$, partial $\eta^2 = .001$.

The intraclass correlation coefficient (ICC) was calculated for each round of assessments with students in grades 1-5 nested within their respective teachers. The ICC was 90.67%, 88.05%, and 90.08% for Round One, Round Two, and Round Three, respectively. Lee (2000) suggests that an ICC greater than 10% indicates a need for multi-level analyses. As a result, two-level hierarchical linear models were used to examine the association between changes in teacher-level variables (teacher beliefs, practices, and content knowledge) and student gain scores for each round of assessments. Changes in teacher practices were dummy coded so that a value of “1” refers to a change to a student-centered practice, as might be expected with the PD, and a value of “0” refers to no change in teacher practices or a change to a teacher-centered practice. Changes in teacher beliefs were also dummy coded so that a value of “1” refers to a change to a discovery/connectionist orientation, as might be expected with the PD, and a value of “0” refers to no change in teacher beliefs or a change to a transmission orientation.

Parameter estimates of the HLM models are presented in Table 4. The gain in teacher content knowledge in mathematics was not statistically significantly related to student gains for any of the three rounds of assessment. This means that the gain in teacher content knowledge during Year Two was not statistically significantly related to the gain in student achievement in mathematics. However, the students of teachers who changed their practices from teacher-centered to student-centered by the end of the year showed significantly more gains during the first round compared to students taught by teachers who did not change their practices or changed their practices from student-centered to teacher-centered. This difference, however, was not statistically significant during the second and third rounds of assessment. Students whose teachers changed their beliefs about teaching mathematics from a transmission to a discovery/connectionist orientation had significantly lower gains during the first and second rounds of assessment than students whose teachers did not change this belief or whose teachers changed from discovery/connectionist to transmission. This difference, however, diminished during the third round of assessment, which means that teachers who changed their beliefs about teaching mathematics from transmission to discovery/connectionist orientation had a significantly positive impact on student achievement because their students were catching up with those taught by other teachers. No statistically significant impacts on the gain scores of student achievement were found for changes in teachers’ beliefs about mathematics or learning mathematics in any of the three rounds of assessment.

Table 4
Parameter Estimates of Two-Level Hierarchical Liner Models

	First Round		Second Round		Third Round	
	Coef.	s.e.	Coef.	s.e.	Coef.	s.e.
Knowledge	-0.43	0.37	-0.23	0.47	-0.59	0.41
Belief in						
Teaching						
T to DC	-11.49	5.04*	-9.14	4.42*	9.21	5.85
Learning						
T to DC	-8.54	6.11	4.72	6.66	-0.24	7.37
Mathematics						
T to DC	-0.80	5.88	1.31	4.72	-2.90	5.38
Teacher Practice						
T to S	11.37	4.35*	0.95	3.95	7.12	4.86

Note. (a) $*p < .05$; (b) T to DC means teacher beliefs changed from a transmission orientation to a discovery/connectionist orientation, and the comparison group was teachers who did not report a change in their beliefs or who changed from a discovery/connectionist to a transmission orientation; and (c) T to S refers to teachers whose practices changed from teacher-centered to student-centered, and the comparison group was teachers whose practices stayed as teacher-centered or changed from student-centered to teacher-centered.

Discussion and Implications

Discussion of Findings

The data analyses indicate that the professional development had a positive influence on teachers' mathematical content knowledge and their instructional practices. Regarding content knowledge, both districts saw gains in their content knowledge. Teachers' mathematical knowledge increased from the pre-test to the post-test as a result of their participation in the professional development. This was positive, considering much of the project focused on practices with content knowledge embedded within various tasks and discussions of specific activities. Although the workshops focused on preparing teachers to implement the *Standards*-based *Investigations* curriculum, the teachers' exploration of cognitively-demanding mathematical tasks and examination of connections between mathematical concepts seem to have positively impacted their performance on the content knowledge assessment. Prior research (Bell, Wilson, Higgins, & McCoach, 2010; Polly, 2012) has similarly found that professional development focusing on both pedagogy and mathematics content can lead to gains in teachers' mathematical content knowledge.

In terms of reported instructional practices, 84 teachers (55.26%) reported a shift from teacher-centered to student-centered practices, whereas 65 (42.76%) remained unchanged. All of those who were unchanged were student-centered prior to the project. A majority of the professional development (over 60 of the 72 hours) focused on effective implementation of *Investigations* and *Standards*-based instructional practices, which may explain the shift towards student-centered pedagogies. Prior pedagogy-specific professional development projects have also found changes of this type in teachers' practices within the first year (Heck et al., 2008; Penuel, Fishman, Yamaguchi, & Gallagher, 2007).

The results were more mixed with regard to teacher beliefs as to whether teachers remained constant, became more transmission oriented (teacher-centered) or more connectionist/discovery oriented (student-centered). Our supplementary qualitative data contains many references to teacher apprehension, especially in Grades 3-5, about whether these pedagogies will lead to student achievement on large-scale tests (McGee, Wang, & Polly, 2013). Previous studies have noted that in some cases teachers require many years to work on shifting their instructional practices before they shift their beliefs (Fennema et al., 1996; Penuel et al., 2007). In this project, however, teachers seemed more willing to shift their instructional practices using *Investigations* before shifting their beliefs. Again, the project's focus on using specific instructional practices might be a possible cause for this finding.

The gains in student learning outcomes showed 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 (Penuel et al., 2007; Polly, 2008; Stigler & Hiebert, 1999). In regards to beliefs, results were mixed: students whose teachers shifted towards transmission views of mathematics teaching outscored peers whose teachers held discovery/connectionist views. However, no statistically significant differences were noted between students whose teachers had shifted from transmission to discovery/connectionist views and their peers whose teachers did not change their beliefs or changed from a discovery/connectionist orientation to a transmission orientation in their beliefs about learning mathematics and mathematics as a subject area. 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.

Implications for Future Work

The findings from this study include implications for future research studies. First, there is a need to reconsider alternative ways to score the curriculum-based assessments in future studies. For the purposes of this study, the researchers scored the assessments numerically, assigning scores to student answers based on teacher-developed rubrics, and then converting the scores to percentages. Since these assessments were curriculum-based, there was not the same number of items on the assessments, and the psychometric properties of the assessments, specifically validity and reliability, are unknown.

Second, evidence about participants' enacted instructional practices was limited to the self-reported data from the Teacher's Practices Questionnaire and validation data collected from a small number of classroom observations. Although prior studies have indicated that survey data on instructional practices aligns with teachers' actual practices (Newfield, 1980), future research studies should collect more classroom observation data to obtain a more elaborate picture of teacher-participants' enacted instructional practices (Desimone, 2009). In the evaluation of large-scale professional development projects, the feasibility of observing large numbers of teachers is problematic (Yoon et al., 2007); solutions using video technologies (Hannafin, Shepherd, & Polly, 2009) may provide an alternative.

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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 (2007). 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 (2007). 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