Innovations in Early Mathematics Professional Development: Benefits to Teachers

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Significance

Professional development (PD) is generally designed to change three aspects of teaching - dispositions toward subject matter, levels and kinds of professional knowledge, and skills around classroom practice – in order to strengthen their capacity to teach in ways that enable a wide range of students to learn. However, the PD in math available to early childhood teachers is limited and largely ineffective (Egert, Fukkink, & Eckhardt, 2018; National Research Council, 2009). Curriculum-specific training tends to be shallow, emphasizing activities and neglecting deep conceptual understanding (Herrington, Herrington, Hoban, & Reid, 2009; Jacob & McGovern, 2015). Further, the dominant model of in-service PD is a one-day workshop; continuing support is rarely available for teacher implementation of new practices (Sarama & DiBiase, 2004). Lastly, PD effectiveness is limited by its lack of a conceptual framework that specifies dimensions of teacher change and guides program design (Chen & Chang, 2006a). This paper describes a quasi-experimental study examining the effects of a 4-year, school-wide professional development (PD) intervention on the dispositions, knowledge, and practice of preschool- through third- grade teachers in a large, urban area in the Midwest.

Method

Sample. Eight intervention schools were identified by the implementation team and school district administrators to participate in the project. Propensity score analysis was used to identify eight schools, out of a pool of 65, that matched intervention schools on key student population demographics and math achievement test scores in third grade. A total of 220 preschool through third-grade teachers participated in research activities. Teacher demographic characteristics are presented in Table 1.

Measures. Three researcher-developed measures were used for assessing teacher outcomes. **Math instructional quality** was assessed by High Impact Strategies in Early Math (HIS-EM) observations were completed by HIS-EM certified staff. Observations were scheduled during the designated math lesson times with the goal of being minimally disruptive to teachers and students and to ensure the observations captured a “typical” lesson. ICCs ranged from 0.35 to 0.85 across dimensions and time points. Correlations between HIS-EM average and Classroom Assessment Scoring System (CLASS; Pianta, La Paro, & Hamre, 2008) ranged from 0.44 to 0.58.

Teacher dispositions toward math and its teaching was assessed using the Attitudes, Beliefs, and Confidence in Early Mathematics (ABC-EM) online survey. ABC-EM consists of 28 statements that made up of two subscales: confidence in math teaching and positive math attitudes. Teachers were asked to rate each statement on a 1 (strongly disagree) to 10 (strongly agree) Likert scale. Both subscales, at all time points, demonstrated an excellent level of internal consistency, ranging from .93 to .95 for Confidence in Math Teaching Subscale and ranging from .90 to .91 for Positive Math Attitudes Subscale.

Teachers' content knowledge for teaching mathematics from pre-K through third grade was captured using the Pedagogical Content Knowledge for Early Mathematics (PCK-EM) online survey. The teacher is asked to watch two videos of authentic teacher-led math lessons (one number sense and one fractions lesson) then answer nine open-ended questions. Responses were assigned codes on a 5-point scale (1 = low: more obvious, behavioral, or procedural to 5 = high: sophisticated/concept) for six facets of PCK (*depth* and *breadth* of content knowledge, understanding of children's *prior math knowledge* and common *misunderstandings*, and knowledge of pedagogical *strategies* and *representations*). ICCs ranged between 0.65 and 0.91 across subcomponents. PCK-EM subcomponent scores were significant predictors of children's math performance.

Intervention. The central conceptual framework that guided the intervention was the Whole Teacher Approach (Chen & Chang, 2006a; 2006b). Analogous to the "whole child" approach in early childhood education, the Whole Teacher Approach suggests that in order to make real changes in teaching, PD must not only address gaps in teacher knowledge, but must be designed to consciously involve teaching practice in learning, and to address teachers' attitudes about teaching and content throughout implementation. The intervention provided four types of PD experiences to teachers (learning labs, summer institutes, coaching, and grade-level meetings), each aimed at increasing teachers' math attitudes, math classroom practice, and math content knowledge. A fifth component (leadership academies) targeted administrators. The intervention lasted 4 years with teachers in the intervention schools receiving professional development throughout the 4-year project period. However, the most intensive individual PD components for teachers occurred in the first 2 years. During the third and fourth years of the PD intervention, the focus changed to efforts to build capacity at the school-level in creating a learning community around teaching and learning math.

Findings

We conducted multilevel intent-to-treat impact analysis comparing intervention and comparison teachers on HIS-EM, ABC-EM, and PCK-EM outcomes controlling for corresponding baseline scores and demographic characteristics. Effect sizes were calculated by dividing the intervention indicator coefficient by the pooled standard deviation of the intervention and comparison group (U.S. Department of Education, 2013).

Math Instructional Quality: Analysis showed that intervention teachers had higher posttest scores than comparison teachers after participating for 1 and 4 years of the intervention (1-year *ES* = 0.65; 4-year *ES* = 1.01; see Table 2). **Teacher dispositions:** Analysis showed that intervention teachers had higher confidence than comparison teachers after the intervention teachers participated in 2 years of the intervention (*ES* = 0.51). One-year and 3-year impacts were not significant. We also found a large intervention effect on confidence scores for the 4-year impact model with an effect size favoring intervention group of 0.71 (see Table 3). **Teacher's content knowledge:** Analysis showed that intervention teachers had higher *Number 7* posttest scores than comparison teachers after teachers participated in 3 years of the intervention ($ES = 0.48$). The 1-year impact was not significant for *Number 7* scores and neither the 1-year nor the 3-year impacts were significant for *Fraction* scores (see Table 4).

Implications

High-quality PD builds on the knowledge base about adult learners (Merriam & Bierema, 2014). This paper contributes to a body of evidence that early childhood teachers benefit from PD that focuses on their instructional practices and pedagogical content knowledge, as well as their dispositions toward math. The benefits of PD are fortified when schools commit to systematic improvement that includes administrative leadership.

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Table 1. Demographic Characteristics of Teachers Participating in Research Activities at Baseline

Characteristic	Intervention (n = 98)		Comparison (n = 85)			
	n	*%*	*n*	*%*	$\chi 2$	*p*
Gender[a]						
Female	66	67.3	45	52.9	---	---
Race[b]						
Black	11	11.2	3	3.5	---	---
Asian	5	5.1	5	5.9	---	---
White	29	29.6	22	25.9	---	---
Other	2	2	0	0	---	---
Ethnicity[b]						
Hispanic	18	18.4	19	22.4	---	---
Language Spoken						
English Only	58	59.2	35	41.2	5.91	0.02
Spanish	33	33.7	43	50.6	5.36	0.02
Other	11	11.2	13	15.3	---	---
Education						
Master's Degree	72	73.5	60	70.6	0.19	0.74
Certification/Endorsement						
Early Childhood	35	35.7	25	29.4	0.82	0.43
Elementary	64	65.3	65	76.5	2.73	0.11
Early Childhood Special Education	13	13.3	2	2.4	7.20	0.01
K-12 Special Education	17	17.3	3	3.5	8.93	0.00
Bilingual/ESL	31	31.6	44	51.8	7.63	0.01
Other	20	20.4	27	31.8	---	---
Years of Teaching Experience						
1-5	30	30.6	20	23.5	---	---
6-10	19	19.4	20	23.5	---	---
11-20	31	31.6	26	30.6	---	---
20+	18	18.4	19	22.4	---	---

Note. [a]66 intervention and 50 comparison teachers provided information about their gender. [b]65 intervention and 50 comparison teachers provided information about their race/ethnicity.

Table 2. HIS-EM Baseline Equivalence and Impact Estimates

	Sample Size				Pretest Equivalence			Posttest		HLM Model Results					
Year	I Clusters (*N*)	I Teachers (*N*)	C Clusters (*N*)	I Teachers (*N*)	I Mean (*SD*)	C Mean (*SD*)	Standardized T-C Difference	I Mean (*SD*)	C Mean (*SD*)	Impact Estimate	Standardized Effect Size	Impact S.E.	*p*	*df*	Improvement Index
1	8	97	8	96	4.0 (1.5)	4.1 (1.3)	-0.09	4.3 (1.1)	3.6 (1.1)	0.73	0.65	0.20	0.003	14	25
2	8	69	8	63	4.0 (1.5)	4.2 (1.2)	-0.21	4.2 (1.3)	3.8 (1.3)	0.52	0.40	0.25	0.057	14	15
3	8	56	7	51	3.9 (1.5)	4.2 (1.2)	-0.18	4.2 (1.2)	4.2 (1.3)	0.07	0.06	0.25	0.787	13	2
4	8	46	6	44	4.0 (1.5)	4.1 (1.2)	-0.16	4.8 (1.4)	3.5 (1.5)	1.45	1.01	0.30	0.0004	12	34

Note. Propensity score weighting was not needed to establish baseline equivalence. I = intervention group; C = comparison group; *n* = sample size. HIS-EM = High-Impact Strategies for Early Mathematics.

Table 3. ABC-EM Baseline Equivalence and Impact Estimates

Models	Sample Size				Pretest Equivalence			Posttest		HLM Model Results					
Subscale	I Clusters (*N*)	I Teachers (*N*)	C Clusters (*N*)	I Teachers (*N*)	I Mean (*SD*)	C Mean (*SD*)	Standardized T-C Difference	I Mean (*SD*)	C Mean (*SD*)	Impact Estimate	Standardized Effect Size	Impact S.E.	*p*	*df*	Improvement Index
Y1 Att	8	83	8	67	6.4 (1.9)	6.7 (1.9)	-0.20	6.4 (1.8)	6.9 (1.9)	-0.21	-0.11	0.18	0.263	14	-8
Y2 Att	8	65	8	49	6.3 (1.8)	6.8 (2.0)	-0.23	6.5 (1.8)	6.9 (1.9)	-0.09	-0.05	0.20	0.683	14	-9
Y3 Att[a]	8	51	6	33	6.3 (1.7)	6.2 (2.3)	0.04	5.9 (1.5)	6.2 (1.7)	0.07	0.04	0.19	0.738	12	2
Y4 Att[a]	7	43	6	33	6.3 (1.6)	6.1 (2.3)	0.09	7.1 (1.6)	6.2 (2.2)	0.64	0.34	0.32	0.069	11	13
Y1 Conf[a]	8	83	8	67	6.9 (1.6)	6.8 (2.0)	0.13	7.6 (1.3)	7.4 (1.7)	0.12	0.08	0.18	0.535	14	3
Y2 Conf[a]	8	65	8	49	7.0 (1.6)	6.7 (1.8)	0.24	8.1 (1.2)	7.2 (1.8)	0.73	0.51	0.29	0.026	14	20
Y3 Conf[a]	8	51	6	33	7.0 (1.6)	6.8 (1.9)	0.12	7.9 (0.9)	7.6 (1.7)	0.23	0.23	0.21	0.289	12	7
Y4 Conf[a]	7	43	6	33	6.9 (1.6)	6.7 (1.9)	0.09	8.4 (1.0)	7.5 (1.4)	0.85	0.71	0.32	0.023	11	26

Note. I = intervention group; C = comparison group; *n* = sample size; ABC-EM = Attitudes, Beliefs, and Confidence for Early Mathematics Att = Attitudes; Conf = Confidence.
[a]Propensity score weighting was used to establish baseline equivalence.

Table 4. Baseline Equivalence and Impact Estimates for PCK-EM Number 7 and Fraction Scores

Models	Sample Size				Pretest Equivalence			Posttest		HLM Model Results					
Video Prompt	I Clusters (*N*)	I Teachers (*N*)	C Clusters (*N*)	C Teachers (*N*)	I Mean (*SD*)	C Mean (*SD*)	Standardized T-C Difference	I Mean (*SD*)	C Mean (*SD*)	Impact Estimate	Standardized Effect Size	Impact S.E.	*p*	*df*	Improvement Index
Y1 PCK-EM Number 7[a]	8	83	8	71	2.5 (0.6)	2.5 (0.6)	-0.02	2.5 (0.6)	2.4 (0.6)	0.12	0.19	0.08	0.157	14	8
Y3 PCK-EM Number 7[a]	8	51	5	25	2.5 (0.6)	2.4 (0.6)	0.11	2.9 (0.8)	2.5 (0.8)	0.37	0.48	0.15	0.031	11	18
Y1 PCK-EM Fraction[a]	8	83	8	67	2.8 (0.7)	2.9 (0.9)	-0.06	2.7 (0.6)	2.7 (0.7)	0.02	0.17	0.11	0.878	14	7
Y3 PCK-EM Fraction[a]	8	51	5	33	2.7 (0.7)	2.7 (0.8)	0.09	2.9 (0.7)	2.7 (0.6)	0.23	0.35	0.13	0.093	12	14

Note. I = intervention group; C = comparison group; *n* = sample size; PCK-EM = Pedagogical Content Knowledge in Early Math.
[a]Propensity score weighting was used to establish baseline equivalence.