Beyond the Horizon: Examining the Associations Among Professional Development, Teachers' Subject-Matter Knowledge, and Student Achievement

Robert C. Schoen, Zahid Kisa, and Amanda Tazaz

Billions of dollars are spent annually on teacher professional development (PD) in the United States (Fermanich, 2002; Odden et al., 2002; TNTP, 2015; U. S. Dept. of Education, 2014; Wei et al., 2010;). Many teacher PD programs have a goal to increase teachers' subject-matter knowledge directly and student learning indirectly. Experimental studies investigating the effect of teacher PD programs on student achievement typically report very small or null effects on student achievement (Garet et al., 2011; Garet et al., 2016; Jacob, Hill, & Corey, 2014, Kennedy, 2016; Schoen, Tazaz, & LaVenia, 2017).

Purpose and Research Questions

The purpose of the present study is to estimate the effect of the Cognitively Guided Instruction (CGI) PD program on teacher Mathematical Knowledge for Teaching (MKT) and the effect of MKT on student learning. The study was guided by the following research questions.

RQ1. What is the effect of CGI on teacher MKT after one and two years of the intervention?

RQ2. To what extent does teacher MKT predict student learning outcomes?

Setting and Sample

Study participants included over 150 first- and second-grade teachers and their students in 22 public schools in two Florida school districts.

CGI PD Program

The current study evaluated the impact of the first two years of a three-year PD model designed and implemented by Teachers Development Group (TDG) under the direction of Linda Levi, one of the co-authors of the definitive CGI book (Carpenter, Fennema, Franke, Levi, & Empson, 1999).

Research Design

To estimate the impact of the program on teacher MKT, the present study uses a multisite cluster-randomized trial evaluation design school-level random assignment to the intervention or comparison condition.

Data Sources

Teachers completed a paper-pencil test of MKT in summer 2013 to be used as a baseline measure of MKT (Learning Math for Teaching, 2004). They completed the Web-based, Knowledge for Teaching Early Elementary Mathematics (K-TEEM; Schoen, Bray, Wolfe, Tazaz, & Nielsen., 2017) test in spring 2014 and again in spring 2015.

Teachers administered the Elementary Mathematics Student Assessment (EMSA) test to students in the first two weeks of each of the 2013–14 and 2014–15 school years (Schoen, LaVenia, Bauduin, & Farina, 2016a; 2016b). Members of the research team administered the Iowa Test of Basic Skills–Math Problems test (Dunbar et al., 2008) to students in spring 2014 and 2015.

Data Analysis

RQ1. To answer RQ1, we perform two cross-sectional analyses using a two-level model with teachers nested in schools. The primary analysis offers a conservative estimate of the impact of the program on teacher MKT. In lieu of a rigorous, treatment-on-the-treated analysis, we also examined the effect of the program using only the teachers in the treatment-condition schools who participated in the CGI PD for two years. Sample sizes are provided in Table 1. The general form for these models is provided in Equation(s) 1. All continuous variables—including the outcome—were standardized.

Teacher Level

$$MKT\text{-}Post_{ij} = \beta_{0j} + \beta_{1j}(MKT\text{-}Pre_{ij}) + \beta_{2j}(Prior\ PD_{ij}) + r_{ij}$$

Eq. 1

School Level

$$\beta_{0j} = \gamma_{00} + \gamma_{01}(CGI\text{-}PD_j) + \gamma_{02}(Percent\ FRL_j) + \gamma_{03}(District_j) + u_{0j}$$

$$\beta_{1j} = \gamma_{10}$$

$$\beta_{2j} = \gamma_{20}$$

Table 1

The number of complete and incomplete cases for the study outcomes and the baseline covariate for the CGI-PD and control groups.

	MKT13 (MKT-Pre)		MKT14 (Year 1 Model Outcome)		MKT15 (Year 2 Model Outcome)	
	Complete	Incomplete-Imputed	Complete	Incomplete-Imputed	Complete	Incomplete-Imputed
CGI-PD	101	28	113	16	102	27
Control	105	47	121	31	120	32

RQ2. We examined the association between teachers' MKT and student achievement using three-level models with students nested within teachers and teachers nested within schools. We did not identify whether teachers were in treatment or control schools. The general form for these models is provided in Equation(s) 2.

Student Level

$$Achievement_{ijk} = \pi_{0jk} + \pi_{1jk}(Achievement\text{-}Pre_{ijk}) + e_{ijk}$$

Teacher Level

$$\pi_{0jk} = \beta_{00k} + \beta_{01k}(MKT_{jk}) + r_{0jk} \qquad \text{Eq. 2}$$

$$\pi_{1jk} = \beta_{10k}$$

School Level

$$\beta_{00k} = \gamma_{000} + \gamma_{001}(Percent\ FRL_k) + \gamma_{002}(District_k) + u_{00k}$$

$$\beta_{01k} = \gamma_{010}$$

$$\beta_{10k} = \gamma_{100}$$

The outcome variable ($Achievement_{ijk}$) was students' scores on the ITBS–Math Problems test. We used ITBS Spring 2014 scores in the year 1 model and Spring 2015 scores in the year 2 model. To control for students' prior mathematics achievement ($Achievement\text{-}Pre_{ijk}$), we used the EMSA test administered in Fall 2013 and in Fall 2014 for year 1 and year 2 model, respectively[1]..

[1] EMSA test were tailored to each grade level and scores were not aligned between the grade levels. Considering that our sample included grade 1 and grade 2 students, we z-scored EMSA tests within each grade and created one combined variable.

To explore a possible delayed effect, we also examined the relationship between student achievement in 2014 and their teachers' mathematical content knowledge measured in 2013 as well as student achievement in 2015 and their teachers' mathematical content knowledge measured in 2014. To be able to compare findings of the concurrent and delayed analyses, in these models, we restricted our sample to teachers who provided data in both study years. All continuous variables, including the outcome,[2] were standardized.

Results

Impact of CGI on Teacher MKT

Results of the HLM models are presented in Table 2. Both models clearly indicate statistically significant, positive impacts of CGI on teacher MKT.

Table 2

Results of HLM analysis estimating the effect of the CGI professional development program on school mean teachers' mathematical knowledge for teaching in year 1 and year 2 of the study.

	Full treatment (Attended the CGI-PD for two years)		All teachers (Attended the CGI-PD for two or one year (s))	
Fixed Effects	End of Year 1 Model	End of Year 2 Model	End of Year 1 Model	End of Year 2 Model
Intercept	-0.49 (0.22) *	-0.31 (0.18)	-0.51 (0.13) **	-0.26 (0.12) *
CGI-PD effect	**0.76 (0.19) *** **	**0.99 (0.14) *** **	**0.48 (0.12) *** **	**0.80 (0.11) *** **
Baseline (Before year 1) teacher knowledge	0.38 (0.07) ***	0.33 (0.07) ***	0.43 (0.05) ***	0.38 (0.06) ***
Prior math PD	0.07 (0.15)	-0.23 (0.14)	0.35 (0.13) *	0.00 (0.13)
Percent FRL students	-0.09 (0.11)	-0.02 (0.08)	-0.10 (0.07)	-0.01 (0.08)
District	0.13 (0.23)	-0.16 (0.18)	0.23 (0.14)	-0.14 (0.12)

Note. SEs are given in parenthesis. * $p \leq 0.05$: ** $p \leq 0.01$; *** $p \leq 0.001$.
Because the intent-to-treat analyses suggested small, not statistically significant effects on the student outcomes (Schoen et al., 2017), we did not meet the necessary preconditions for mediational analysis. The *all-teachers* models used data from 129 CGI-PD and 152 control-group teachers who participated study at any study year. The *full-treatment* models used data from 74 CGI-PD and 73 control group teachers who participated the study for two years.

Effect of Teacher MKT on Student Learning

[2] ITBS scores of grade 1 students were not equated with ITBS scores of grade 2 students. Thus, we standardized outcome variable within grade levels.

Model results in Table 3 suggest that there was no concurrent relationship between teachers' mathematical knowledge for teaching and their students' math achievement within the same school year, but there appears to be a small, delayed effect of MKT on student achievement.

Table 3

Results of HLM analysis estimating the concurrent and delayed relationship between teachers' mathematical knowledge for teaching and student achievement on ITBS problem solving.

	Concurrent Associations	Delayed Associations
Year 1- ITBS 2014	MKT measured in 2014	MKT measured in 2013
	Problem Solving	Problem Solving
Intercept	-0.04 (0.05)	-0.04 (0.05)
MKT	**0.04 (0.03)**	**0.04 (0.03)** ~
Students' pre-test score (Before Fall 2013)	0.62 (0.02) ***	0.62 (0.02) ***
Percent FRL students	-0.14 (0.03) ***	-0.15 (0.03) ***
District	-0.00 (0.07)	-0.00 (0.07)
Year 2- ITBS 2015	MKT measured in 2015	MKT measured in 2014
	Problem Solving	Problem Solving
Intercept	0.08 (0.05)	0.09 (0.05) ~
MKT	**0.03 (0.02)**	**0.05 (0.02) ***
Students' pre-test score (Before Fall 2014)	0.66 (0.02) ***	0.66 (0.02) ***
Percent FRL students	-0.14 (0.03) ***	-0.13 (0.03) ***
District	-0.13 (0.06) *	-0.15 (0.06) *

Notes. SEs are given in parenthesis. ~ $p \leq 0.10$ * $p \leq 0.05$: ** $p \leq 0.01$; *** $p \leq 0.001$.
Results of these correlational analyses should be considered exploratory.
The random effect of the slope of teacher MKT and student achievement was not statistically significant in any of the models. This suggest that the relationship between teacher knowledge and student achievement didn't vary between schools. Although there was no significant variation on the slope to explain, we examined cross-level interaction effect and found no significant results, which suggested that the relationship between teacher knowledge and students' achievement was not different in CGI-PD schools than in control group schools.

Conclusions

CGI clearly made a large, positive impact on teacher MKT. The magnitude of the impact on MKT was greater after the second year of intervention than after the first.

The effects of MKT on student achievement were not observed concurrently, but they appear when MKT is measured at the end of the previous school year. The size of the effect was small; a one-standard-deviation increase in MKT was related to 0.04–0.05 standard deviations increase in student achievement.

Evaluations of the effect of teacher PD programs on student achievement almost exclusively expect effects on students to occur concurrently with the teacher PD program, or at least within the same year the intervention occurred (Kennedy, manuscript in progress). Maybe the PD programs are not affecting student achievement in a measureable way (Garet et al., 2016), or maybe there are so many other factors related to teaching and learning that the noise is overwhelming the signal (Hill et al., 2018). The results of the present study suggest that program evaluators may need to consider looking for effects of teacher PD programs on student achievement in the year(s) following the PD intervention rather than concurrently with it.

References

Carpenter, T. P., Fennema, E., Peterson, P. L., Chiang, C.P., & Loef, M. (1989). Using knowledge of children's mathematics thinking in classroom teaching: An experimental study. *American Educational Research Journal, 26* (4), 385-531.

Carpenter, T. P., Fennema, E., Franke, M. L., Levi, L, Empson, S. B. (1999). *Children's mathematics: Cognitively guided instruction.* Portsmouth, NH: Heinemann.

Dunbar, S. B., Hoover, H. D., & Frisbie, D. A., Ordman, V. L., Oberley, K. R., Naylor, R. J., & and Bray, G. B. (2008). *Iowa Test of Basic Skills®*. Rolling Meadows, IL: Riverside Publishing.

Fermanich, M. L. (2002). School spending for professional development: A cross-case analysis of seven schools in one urban district. *The Elementary School Journal, 103*(1), 27–50.

Garet, M. S., Heppen, J. B., Walters, K., Parkinson, J., Smith, T. M., Song, M., Garrett, R., Yang, R., & Borman, G. D. (2016). *Focusing on mathematical knowledge: The impact of content-intensive teacher professional development* (NCEE 2016-4010). Washington, DC: National Center for Education Evaluation and Regional Assistance, Institute of Education Sciences, U.S. Department of Education.

Gersten, R., Taylor, M. J., Keys, T. D., Rolfhus, E., & Newman-Gonchar, R. (2014). Summary of research on the effectiveness of math professional development approaches. Tallahassee: Regional Educational Laboratory Southeast, Florida State University. Retrieved June 30, 2014 from http://ies.ed.gov/ncee/edlabs/regions/southeast/pdf/REL_2014010.pdf.

Hill, H., Charalambous, C. Y., & Chin, M. J. (2018). Teacher characteristics and student learning in mathematics: A comprehensive assessment. *Educational Policy, 00*(0), 1–32.

Kennedy, M. (2016). How does professional development improve teaching? *Review of Educational Research, 86*(4), 945–980.

Kennedy, M. How we learn about teacher learning. Manuscript in progress.

Learning Mathematics for Teaching. (2004). *Mathematical knowledge for teaching measures:*

Geometry content knowledge, number concepts and operations content knowledge, and patterns and algebra content knowledge. Ann Arbor, MI: Learning Mathematics for Teaching.

Schoen, R. C., Bray, W., Wolfe, C., Nielsen, L., & Tazaz, A. M. (2017). Developing an assessment instrument to measure early elementary teachers' mathematical knowledge for teaching. *The Elementary School Journal, 118(1).*

Schoen, R. C., LaVenia, M., Bauduin, C., & Farina, K. (2016a). *Elementary mathematics student assessment: Measuring the performance of grade 1 and 2 students in counting, word problems, and computation in fall 2014* (Research Report No. 2016-04). Tallahassee, FL: Learning Systems Institute, Florida State University. https://doi.org/10.17125/fsu.1508174887

Schoen, R. C., LaVenia, M., Bauduin, C., & Farina, K. (2016b). *Elementary mathematics student assessment: Measuring the performance of grade 1 and 2 students in counting, word problems, and computation in fall 2013* (Research Report No. 2016-03). Tallahassee, FL: Learning Systems Institute, Florida State University. https://doi.org/10.17125/fsu.1508170543

Schoen, R.C., Lavenia, M., & Tazaz, A. (2017, March). *Effects of a Two-year Cognitively Guided Instruction Professional Development Program on First- and Second-Grade Student Achievement in Mathematics.* Paper presented at the spring conference of the Society for Research in Educational Effectiveness, Washington, DC.

Schoen, R. C., LaVenia, M., Tazaz, A., Farina, K., Dixon, J. K., & Secada, W. G. (2017). *Replicating the CGI experiment in diverse environments: Effects of year 1 on student mathematics achievement* (Research Report No. 2017–01). Tallahassee, FL: Florida State University, Learning Systems Institute.

U.S. Department of Education. (2014). *Fiscal year 2014 budget summary and background information*. Washington, DC: Author. Retrieved from http://www2.ed.gov/about/overview/budget/budget14/summary/14summary.pdf

Wei, R. C., Darling-Hammond, L., and Adamson, F. (2010). *Professional Development in the United States: Trends and Challenges*. Dallas, TX: National Staff Development Council.