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THE RELATIONSHIP BETWEEN TEACHER RELATED FACTORS AND MATHEMATICS TEACHERS' EDUCATIONAL BELIEFS ABOUT MATHEMATICS

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This study investigates the extent to which: (a) mathematics teachers' educational beliefs about mathematics change upon participation in professional development, and (b) teachers' educational background and teaching experience in mathematics contribute to their educational beliefs and to the change in these beliefs. Results showed that teachers significantly improved their educational beliefs about mathematics after professional development. Multiple regression analyses revealed that mathematics teaching experience predicted self-efficacy in teaching mathematics at program onset whereas mathematics college hours predicted the change in self-efficacy in teaching mathematics. The paper discusses the implication of findings for preparation and professional development of mathematics teachers.

At a time when certain measures of teacher quality are reduced to the growth of their students' learning, it is critical not to discount the educational beliefs associated with effective teaching. Several types of educational beliefs held by teachers have been identified as adaptive and associated with student success (e.g., Caprara, Barbaranelli, Steca, & Malone, 2006); however, little research has investigated the antecedents of these beliefs among practicing mathematics teachers (Stevens, Aguirre-Munoz, Harris, Higgins, & Liu, 2013). Moreover, research examining the extent to which professional development (PD) can promote these educational beliefs is scant. PD of teachers has been identified as one of the key factors of improving public education (Borko, 2004). Studies show that PD programs for teachers can improve not only teachers' knowledge and skills but also their beliefs, attitudes, and instructional practices with consideration of contextual factors such as school leadership and policy, curriculum, and characteristics of teachers and students (Desimone, 2009).

Theoretical Background

The focus of this paper was to examine antecedents of teachers' self-efficacy, internal locus of control, and epistemic beliefs. Teachers' self-efficacy may be defined as the extent to which teachers believe they can successfully execute teaching-related tasks within a particular context (Tschannen-Moran & Hoy, 2001). Initial work attempting to conceptualize and operationalize teachers' self-efficacy beliefs stemmed from a theory of locus of control (Rotter, 1966). Measures informed by this theory assessed how much control teachers felt they had over student outcomes regardless of external circumstances (e.g., outcome expectancy; Enochs,

Smith, & Huinker, 2000). However, subsequent instruments developed to assess teachers' self-efficacy were more aligned with Bandura's (1986) definition of self-efficacy within a social-cognitive framework (Tschannen-Moran & Hoy, 2001). Thus, education researchers proposed that like other social-cognitive types of self-efficacy, teachers' self-efficacy is influenced by personal mastery experiences, vicarious experiences (observation of models), social persuasion, and physiological indicators (Schunk, Pintrich, & Meece, 2008). Proxies for these influential sources of teachers' self-efficacy examined in previous research include teaching experience, educational background in subject matter taught, and PD (Evans, 2014; Stevens et al., 2013; Wolters & Daugherty, 2007).

Locus of control beliefs are considered a motivational dimension within attribution theory that captures whether a person ascribes the causal factors of personal behavior and the behavior of others as being either internal or external (Weiner, 1992). Teachers' locus of control has been conceptualized as the extent to which teachers attribute student outcomes (i.e., achievement) to themselves or external factors (Rose & Medway, 1981). Prior findings indicate that an internal locus of control positively predicts job performance among teachers (Jeloudar & Lotfi-Goodarzi, 2012) and adaptive classroom behavior among students (Rose & Medway, 1981). Furthermore, research shows that an association exists between certification type (traditional vs. alternative) and teachers' beliefs about how much control they have over students' achievement-related outcomes (Evans, 2014).

Epistemic beliefs can be defined as an individual's beliefs about knowledge, which includes one's beliefs about where knowledge comes from, what the essence of knowledge is, and how one comes to know and justify beliefs. Educational psychology research has conceptualized and measured epistemic beliefs as residing across two ends of a spectrum. On one end, individuals believe that knowledge is fixed, simple, certain, objective, and comes from a person of authority. Muis (2004) classifies beliefs at this end of the spectrum as non-availing epistemic beliefs. Conversely, individuals classified as having availing epistemic beliefs view knowledge as evolving, complex, uncertain, subjective, and stemming from their own construction of knowledge. Availing epistemic beliefs are associated with positive motivational processes and academic achievement (Muis, 2004). Unfortunately, common characteristics of mathematics instruction (i.e., single formulaic approach to problem solving) hinder the development of more availing beliefs about knowledge. Therefore, in line with suggestions from

previous researchers, it is imperative to examine antecedents of teachers' epistemic beliefs as these beliefs have been shown to influence instructional approaches, and in turn, students' own epistemic beliefs (Hofer, 2001; Muis, 2004).

The following research questions guided this study: (1) Did mathematics teachers' educational beliefs about mathematics change after a PD program? (2) What is the predictive value of background variables such as teaching experience, college mathematics hours, and teacher preparation route on teachers' beliefs about teaching and learning mathematics?

Method

This paper is a part of a larger study where we surveyed K-12 in-service teachers, who participated in three-week rigorous PD program. The PD aimed at improving teachers' pedagogical content knowledge (PCK)—the knowledge that they “*use in classrooms to produce instruction and student growth*” (Hill, Ball, & Schilling, 2008, p. 374). This included *knowledge of content and students*, *knowledge of content and teaching*, and *knowledge of curriculum* (Hill et al., 2008). We focused on two cohorts who participated in the study over the course of two summers (2013 & 2014) for this paper. Teachers either volunteered or were selected by their school administration to participate in the summer campus programs (SCP). The mathematical content focus of the 2013 SCP (first cohort) was: (a) numbers, operations, and quantitative reasoning; and (b) patterns, relationships, and algebraic reasoning. The content focus of the 2014 SCP (second cohort) was: (a) geometry, spatial sense, and measurement; and (b) data analysis, statistics, and probability. Both SCPs emphasized following research-based pedagogical constructs: active learning approach; motivation, applications, and problem-solving; and concept-based learning activities (e.g., Erickson, 2007; Pajares, & Graham, 1999). The total duration of each SCP was 72 contact hours (3 weeks; 4 days a week; and 6 hours a day).

In this study, 151 K-12 mathematics teachers (80 from cohort 1 and 71 from cohort 2) representing several urban school districts in the southwestern U.S. took pre- and post-surveys. Demographic breakdown of the teachers were 25% White, 39% African American, 26% Hispanic, 8% Asian, and 2% other. There were 118 female teachers (78%) and 33 male teachers (22%). Of all the teachers, 42 attended the elementary class (grades K-3); 35 attended the intermediate class (grades 4-6); 38 attended the middle school class (grades 7-8); and 36 attended the high school class (grades 9-12). On average, teachers took 21 college mathematics hours and had 3.5 years of mathematics teaching experience. In terms of preparation route, 42% had a

traditional teacher preparation or master of arts in teaching, 50% went through alternative certification program, and 8% took other preparation routes (e.g., emergency, deficiency plan).

Participating teachers took a pre-survey two to three weeks prior to each SCP and a post-survey the last day of the SCPs. The survey items assessed teachers' self-efficacy in teaching mathematics, internal locus of control, and non-availing epistemic beliefs.

The survey consisted of several sections: 1) demographics, 2) teacher preparation background, and 3) Likert-scaled items adapted from previous scales (Mathematics Beliefs Instrument [Schoenfeld, 1989] and Mathematics Teaching Efficacy Belief Instrument [Enochs et al., 2000]) with adequate reliability and validity measuring the main constructs. All Likert-scaled items included in this study were rated on scales ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating higher presence of the construct. Constructs and sample items are as follows: A measure of self-efficacy in teaching mathematics (e.g., *"I know the steps to teach mathematics concepts effectively"* [Enochs et al., 2000]), internal locus of control (e.g., *"Students' achievement in mathematics is directly related to their teacher's effectiveness in mathematics teaching"* [Enochs et al., 2000]), and non-availing epistemic beliefs about mathematics (e.g., *"Everything important about mathematics is already known by mathematicians"* [Schoenfeld, 1989]). Higher scores on the first two constructs are more adaptive; whereas, higher scores on the last construct—non-availing epistemic beliefs, are less adaptive.

The measures of self-efficacy in teaching mathematics (13 items), internal locus of control (8 items), and non-availing epistemic beliefs about mathematics (7 items) all had good reliabilities (with Cronbach's α 's of 0.85, 0.75, and 0.72, respectively [Nunnally & Bernstein, 1994]). We calculated teachers' average scores (from 1 to 5) of all items as a composite score on each measure of educational beliefs for the pre- and post-surveys.

First, we compared the results of post-survey with that of pre-survey to explore the change in beliefs throughout PD to answer the first research question. Then, we investigated the predictive value of teacher-related background variables on the beliefs and the change in these beliefs from pre- to post-survey to answer the second research question.

Findings

We conducted paired-samples *t*-tests to investigate whether changes occurred in teachers' beliefs. Overall, the changes were significant ($p < .01$) with moderate effect sizes (0.47 to 0.64):

teachers' self-efficacy in teaching mathematics and internal locus of control increased (0.22 and 0.21 points, respectively) while their non-availing epistemic beliefs decreased (0.28 points; see Table 1). Then, we divided teachers into two groups (grades K-6 and grades 7-12) to see if changes in beliefs differed by grade level given that previous research indicates that elementary teachers have less mathematics background compared to higher grades. We conducted independent-samples *t*-tests to compare the two groups of teachers. Although there was not a significant difference ($p > .05$) on the pre-survey, K-6th grade teachers showed more change (growth) in their self-efficacy beliefs in teaching mathematics than 7th-12th grade mathematics teachers ($p < .01$ with an effect size of .55; see Table 2).

Table 1. *Paired-Samples t-test Results for Change in Measures of Teachers' Educational Beliefs*

Survey	Paired differences (post-pre)				Cohen's <i>d</i>
	N	Mean gain	S.D.	<i>t</i> -value	
Self-efficacy in teaching math	151	0.21905	0.42055	6.401*	.520
Internal locus of control	151	0.21109	0.45396	5.714*	.465
Non-availing epistemic beliefs	151	-0.28477	0.44523	-7.859*	.640

Notes. * $p < .01$.

Table 2. *Independent-Samples t-test Results for Comparing Change in Beliefs between Grade Levels*

Survey	N		Mean gain		S.D.		<i>t</i> -value	Cohen's <i>d</i>
	K-6	7-12	K-6	7-12	K-6	7-12		
Δ Self-efficacy in teaching math	77	74	0.33	0.11	0.47	0.33	11.416*	.551
Δ Internal locus of control	77	74	0.22	0.21	0.42	0.49	0.018	-
Δ Non-availing epistemic beliefs	77	74	-0.34	-0.27	0.47	0.43	2.566	-

Notes. * $p < .01$.

Table 3 shows means, standard deviations, and correlation coefficients among teachers' background variables, their scores on belief measures, and the change in belief scores. Results revealed that higher self-efficacy in teaching mathematics was associated with more availing epistemic beliefs ($r = -.20, p < .05$). Teachers' pre-survey scores in the three belief measures were negatively associated with growth in those measures (with r 's ranging from $-.56$ to $-.33, p < .01$). This was an expected result simply because teachers who began with higher scores had less room for improvement.

Table 3. Means, Standard Deviations, and Pearson Correlations among the Main Variables

Variable	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7	8	9
1. Years of math teaching	3.52	4.06	---								
2. Math college hours	21.6	15.8	.00	---							
3. Trad. teacher prep route	0.42	0.50	-.11	-.07	---						
4. Other prep route	0.08	0.27	.24	.30**	-.25**	---					
5. SE in teaching math	4.04	0.49	.21**	.07	.00	.12	---				
6. Internal locus of control	3.51	0.48	.07	-.06	-.15	.12	.11	---			
7. Epist. beliefs (non-avail.)	2.25	0.52	.06	-.04	-.02	.01	-.20*	-.08	---		
8. Δ SE in teaching math	0.22	0.42	-.08	-.19*	-.04	.00	-.56**	.03	.09	---	
9. Δ Internal locus of control	0.22	0.46	.00	.02	-.01	-.05	-.08	-.33**	.09	.21**	---
10. Δ Epist. beliefs (non-avail.)	-0.28	0.44	.07	.12	.02	.09	.05	-.12	-.41**	-.11	.01

Notes. $N = 148$; * $p < .05$. ** $p < .01$.

Table 4 shows the results of six two-step hierarchical regression analyses conducted to predict the three belief measures and the change in these three measures. Variables associated with mathematics background were entered in the first step while preparation route variables were entered in the second as the first group of variables are specific to mathematics content.

Table 4. Summary of Hierarchical Regression Analyses Predicting Educational Beliefs Among Mathematics Teachers

Variable	Self-efficacy in teaching math ^a	Internal locus of control ^b	Non-availing epistemic beliefs ^c	Δ Self-efficacy in teaching math ^d	Δ Internal locus of control ^e	Δ Non-availing epistemic beliefs ^f
	β	β	β	β	β	β
Step 1 (math background)						
Years of math teaching	.20*	.03	.06	-.08	.02	.06
Math college hours	.05	-.10	-.04	-.21*	.04	.11
Step 2 (teacher prep route)						
Traditional	.05	-.12	-.01	-.05	-.02	.04
Other	.07	.11	.00	.08	-.08	.05

Notes. β indicates standardized regression coefficient. $N = 148$. * $p < .05$. *ns* = not significant.

^a Step 1/Step2: $R^2 = .05$, $p < .05$ / $\Delta R^2 = .01$, *ns*. ^b Step 1/Step2: $R^2 = .01$, *ns* / $\Delta R^2 = .01$, *ns*. ^c Step 1/Step2: $R^2 = .01$, *ns* / $\Delta R^2 = .00$, *ns*. ^d Step 1/Step2: $R^2 = .05$, $p < .05$ / $\Delta R^2 = .01$, $p > .01$. ^e Step 1/Step2: $R^2 = .00$, *ns* / $\Delta R^2 = .01$, *ns*. ^f Step 1/Step2: $R^2 = .01$, *ns* / $\Delta R^2 = .00$, *ns*.

In the regression predicting self-efficacy in teaching mathematics, after entering the two math background variables in Step 1, the model was statistically significant ($F(2, 145) = 3.84, p < .05, R^2 = 5\%$). Specifically, years of experience in mathematics teaching emerged as statistically significant ($\beta = .21, p < .05$). In the regression predicting change in mathematics teaching self-efficacy, Step 1 was statistically significant ($F(2, 145) = 3.08, p < .05, R^2 = 4\%$). The number of mathematics college hours earned was statistically significant ($\beta = -.21, p < .05$).

Discussion and Conclusions

This study informs us about the potential motivational benefits of a PD program focusing on PCK and expands our knowledge of antecedents associated with several educational beliefs among K-12 mathematics teachers. Findings suggest that PD aimed at enhancing PCK not only improves teachers' PCK but also promotes teachers' adaptive educational beliefs about mathematics (self-efficacy in teaching math, internal locus of control, and availing epistemic beliefs). This supports that a relationship exists between teachers' PCK and their beliefs (Desimone, 2009). Since PCK involves knowledge of content and students, knowledge of content and teaching, and knowledge of curriculum (Hill et al., 2008), improving these aspects would yield more adaptive beliefs relating to mathematics knowledge for teaching.

In terms of antecedents of teachers' educational beliefs, years of experience in mathematics teaching emerges as positively associated with self-efficacy beliefs in teaching mathematics at the onset of the PD program. This finding is expected and consistent with previous research (Wolters & Daugherty, 2007), as one would assume that more experienced teachers are likely to know more about teaching and the content they teach, and in turn, feel more confident in successfully performing mathematics teaching related tasks.

Teachers' mathematical background, specifically the number of mathematics hours taken at college, can serve as a moderator in the extent that teachers enhance their self-efficacy in teaching mathematics throughout a PD program. In other words, teachers who enter the program with less college mathematics hours are more likely to grow in mathematics teaching self-efficacy compared to their counterparts who have more college mathematics hours. This finding suggests that having a strong background in math content plays a role in teachers' beliefs about their ability to be effective teachers (Stevens et al., 2013). The practical implications for PD programs include providing more support and scaffolding to teachers who lack a strong background in the subject matter they teach so that their PCK, and in turn, self-efficacy for

teaching mathematics grow (Desimone, 2009). However, future studies are needed to elucidate which aspects of PD enhance various types of educational beliefs among mathematics teachers.

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