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Critical Responses to Enduring Challenges in Mathematics Education

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THE COLLECTIVE EFFECTS OF TEACHERS' EDUCATIONAL BELIEFS AND MATHEMATICAL KNOWLEDGE ON STUDENTS' MATHEMATICS ACHIEVEMENT

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Research suggests that teachers' knowledge and beliefs about teaching and learning mathematics are among the key factors for effective teaching. This study explores the extent to which K-12 mathematics teachers' educational beliefs and mathematics knowledge for teaching (MKT) have an impact on students' math achievement. The effects of students' prior math achievement and teachers' years of experience and mathematics degrees earned were also examined. Hierarchical regression analysis results indicated that prior achievement was a significant student-level predictor of mathematics achievement. Teachers' MKT and teaching experience also had a significant effect on the relation between prior achievement and current achievement. Results may have implications for teacher professional development programs as well as education policies at both district and state level.

Keywords: Mathematical Knowledge for Teaching, Teacher Beliefs, Teacher Education-Inservice/Professional Development, Teacher Knowledge

Purpose of the Study

A significant body of research highlights the integral role that teachers' domain-specific knowledge for teaching and their educational beliefs about teaching have on their knowledge development, decision-making and planning, and instructional practices (e.g., Parajes, 1992; Philipp, 2007). Adding to this line of research, this report extends our findings from a larger study that examined both antecedents and outcomes of teachers' beliefs about teaching and learning mathematics (Ekmekci, Corkin, & Papakonstantinou, 2015) by connecting teachers' beliefs and their mathematical knowledge for teaching (MKT) to student outcomes. Specifically, the current study is guided by the following research questions: (a) to what extent does a student's prior mathematics achievement relate to their subsequent mathematics achievement, (b) to what extent do teacher-level characteristics (e.g., experience, beliefs, and MKT) relate to students' math achievement, and (c) to what extent do the effects of student-level factors on math achievement vary by teacher-level characteristics?

Literature Review

Teachers' personal and domain-specific educational beliefs should not be overlooked in the evaluation and development of effective instruction (Stipek, Givvin, Salman, & MacGyvers, 2001). There are various types of educational beliefs that math teachers possess such as self-efficacy beliefs, locus of control beliefs, and epistemic beliefs about mathematics that influence their instructional approaches (e.g., Stipek et al., 2001). Teachers' self-efficacy can be defined as the degree to which teachers believe they can successfully perform teaching-related tasks within a particular domain or context (Enochs, Smith, & Huinker, 2000). Teachers' locus of control may be defined as the extent to which teachers attribute student outcomes (i.e., achievement) to themselves or other (external) factors (Hofer & Pintrich, 1997). Epistemic beliefs can be perceived as beliefs about the nature of knowledge—i.e., where it comes from, its essence, and how one comes to know (Muis, 2004).

Prior studies have found a strong association between teachers' beliefs and students'

achievement-related outcomes (e.g., Goddard, Hoy, & Woolfolk-Hoy, 2000; Love & Kruger, 2005). However, the vast majority of these studies focused on only one type of belief (e.g., self-efficacy) and failed to scrutinize the collective impact of different types of beliefs on student achievement. Moreover, the relation between teachers' domain-specific beliefs and student outcomes has not been adequately addressed in previous research.

In addition to teachers' educational beliefs, MKT, defined as "the mathematical knowledge that teachers use in classrooms to produce instruction and student growth" (Hill, Ball, & Schilling, 2008, p. 374), has been found to positively relate to student performance (Hill, Rowan, & Ball, 2005). While previous findings indicate that each of the aforementioned beliefs and knowledge are associated with student achievement, no studies were identified that examined the varying effects of each of these beliefs on students' mathematics achievement. Questions remain as to whether certain educational beliefs have stronger effects on students' mathematics achievement compared to other educational beliefs. Preliminary findings suggest that certain beliefs may play a more important role in student achievement in mathematics given that Ekmekci, Corkin, and Papakonstantinou (2015) found that among these three beliefs, a teachers' epistemic beliefs about mathematics is the strongest predictor of a teachers' MKT, which is a reflection of their instructional practices (Hill et al., 2008).

In terms of teachers' professional background, years of teaching experience has been positively associated with teacher quality (see Rice [2003] for review; 2010). A second teacher background variable that has been linked to student achievement is teachers' educational background in the subject matter that they teach. The majority of the research that examines the influence of educational background in a teaching discipline assesses its impact on student-related outcomes (Barry, 2010). Given the significant relations that have been found between teachers' educational and experiential background with student achievement, the current study will examine the extent to which teachers' beliefs and MKT explain the variation in student performance after accounting for these variables.

Conceptual Framework

The conceptual model in Figure 1 provides a representation of our multilevel research design. Arrow A displays the direct link between the student's prior math achievement (level-1) and math achievement as the outcome variable. The main effects of the teacher-level variables (level-2) on math achievement are depicted by arrow B. Arrow C represents the effects of teacher-level variables on the relation between students' prior and current math achievement (e.g. does the predictive value of prior achievement change by level of teacher experience?).

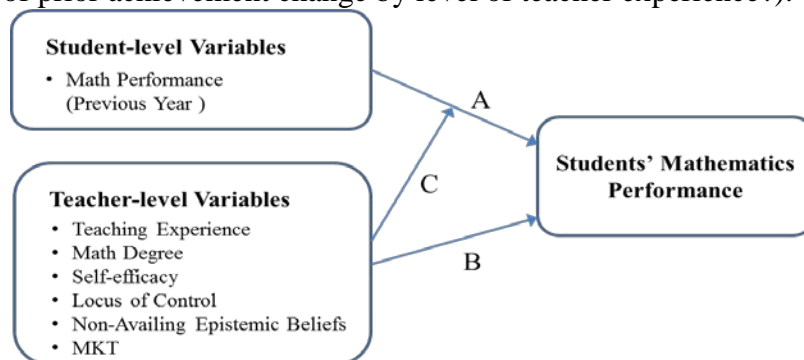


Figure 1: Conceptual Model of the Study

Methodology

The teacher-level data for this study has been collected as part of a project that was partially funded by Teacher Quality Grants Program at the Texas Higher Education Coordinating Board

under Grants #496. For the past two years, consistent measures were administered to assess teachers' educational beliefs after a summer campus program (SCP)—a three-week intensive professional development program aimed at improving mathematics teachers' MKT. Participating teachers took a post-survey on the last day of the SCP assessing teachers' self-efficacy for teaching mathematics, internal locus of control, and epistemic beliefs about mathematics. The teachers also took the Learning Mathematics for Teaching (LMT) assessment, a standardized assessment that measures MKT (Hill, Ball, & Schilling, 2008), on the last day of the program. More specifically, elementary teachers took El NCOP 2008 scale and middle and high school teachers took MS PFA 2007 scale.

In addition to these measures, teacher level variables included professional background variables such as years of teaching experience and whether teachers had earned a mathematics degree. Student level data requested from the school district included student scores on a standardized mathematics test that was administered at the end of the academic year. The ongoing study will continue to collect data from 2014 teachers and students. Although 2014 teacher data is readily available, since the student achievement data for this cohort is not available yet, this brief only reports the findings for the 2013 cohort.

Table 1: Standardized Coefficients for Linear Mixed Effects Model Results

Independent Variable	Model 1 (unconditional)		Model 2 (within teacher)		Model 3 (between teacher)	
	β	SE	β	SE	β	SE
<i>Fixed Effects</i>						
Intercept	0.03	0.10	0.02	0.11	0.21	0.16
Prior Math Achievement			0.79***	0.02	0.85***	0.05
Math Degree					0.42*	0.19
Years of Teaching					0.09	0.11
Self-Efficacy					-0.19	0.16
Locus of Control					0.02	0.12
Epistemic Beliefs					0.28	0.16
LMT					0.06	0.15
Prior Math Achievement X						
<i>Math Degree</i>					0.08	0.06
<i>Years of Teaching</i>					0.06*	0.03
<i>Self-Efficacy</i>					-0.02	0.03
<i>Locus of Control</i>					0.02	0.03
<i>Epistemic Beliefs</i>					0.00	0.04
<i>LMT</i>					0.04*	0.03
<i>Random Effects (Variance Components)</i>						
Student-level effect $r_{ij}(\sigma^2)$	0.77***	0.03	0.30***	0.01	0.29***	0.01
Intercept Teacher mean, u_{0j}	0.26**	0.08	0.26**	0.09	0.24*	0.10
Slope, $u_{1j}(\tau_{1j})$					0.00	0.01
Wald Z (Variance explained)	3.260** (25%)		2.864** (64%)		2.660** (9%)	
AIC / BIC	3775 / 3785		1938 / 1948		1932 / 1942	

* $p < .05$. ** $p < .01$. *** $p < .001$

Among the 51 K-12 teachers who participated in the 2013 SCP, 77% were female; 38% were African American, 30% Hispanic, 20% White, 10% Asian, and 2% other. Students' ethnic background breakdown in the school district is as follows: 29% are African American, 58% Hispanic, 9% White, 10% Asian, and 2% other. About 23% were high school teachers; 26% were middle school; and 51% were elementary teachers. We used linear mixed effects model

(multilevel regression) in SPSS to conduct our analyses. We standardized all variables (computed *z*-scores) before entry into the regression analyses to obtain standardized coefficients in the SPSS regression output for an easy interpretation as one standard deviation increase in each independent variable on standard deviation change in mathematics achievement (Hill et al., 2005). The hierarchical linear models are as follows:

Level-1 (student level): $Y_{ij}(\text{nce14}) = \beta_{0j} + \beta_{1j}(\text{nce13})_{ij} + r_{ij}$

Level-2 (teacher level): $\beta_{qj} = \gamma_{q0} + \gamma_{q1}(\text{MathDeg}_j) + \gamma_{q2}(\text{YearsOfTeach}_j) + \gamma_{q3}(\text{SelfEff}_j) + \gamma_{q4}(\text{LocusOfCont}_j) + \gamma_{q5}(\text{EpsBeliefs}_j) + \gamma_{q6}(\text{MKT}_j) + u_{qj}$

Results and Discussion

The results showed that teacher-level variation accounted for a significant amount (about 26%) of the variation in math achievement (unconditional model; Wald $Z = 3.26$, $p < .01$). Table 1 displays the results for the within-teacher (Model 2) and between-teacher (Model 3) predicting the student achievement outcome. Findings showed that the only significant stand-alone predictors were students' mathematics achievement in the previous year (corresponds to Arrow A in Figure 1) and teachers' mathematics degree (part of arrow B in Figure 1). None of the three types of teachers' beliefs were significantly associated with student achievement in math (Arrow B). However, teachers' MKT and years of experience both had a statistically significant effect on the relation between prior achievement and current mathematics achievement (Arrow C). This implies that the predictive value of prior achievement on students' mathematics achievement varies by teachers' MKT and teaching experience. More specifically, higher MKT (i.e., LMT scores) and greater years of teaching experience strengthens the relation between students' prior and current mathematics achievement. Figures 2 and 3 depicts this moderating effect of experience and MKT on mathematics achievement.

These results suggest that having a mathematics degree (which generally implies more advanced coursework in mathematics) positively affects student achievement. Teacher educators should also pay close attention to developing teachers' MKT. Urban school districts may consider hiring more experienced teachers to boost their students' academic achievement. Lastly, teacher preparation programs should look for ways to offer more mathematics content and methods courses to improve their MKT.

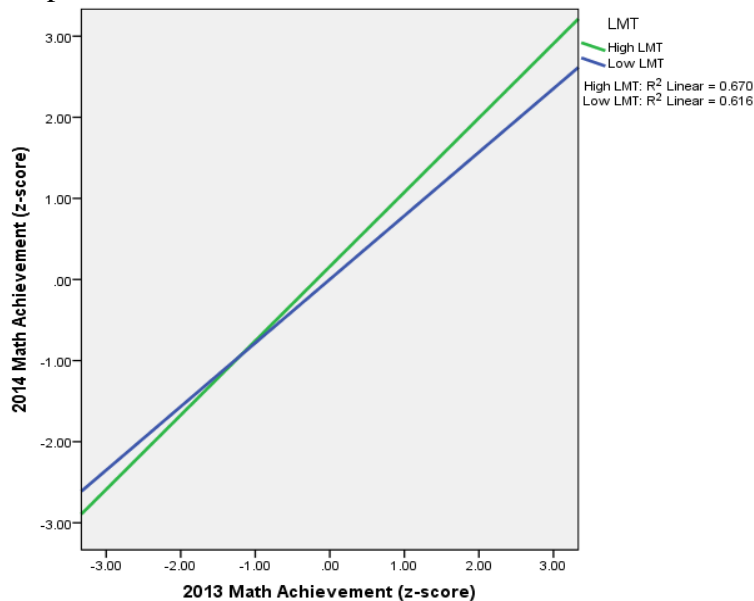


Figure 2. Moderating Effect of MKT on Math Achievement

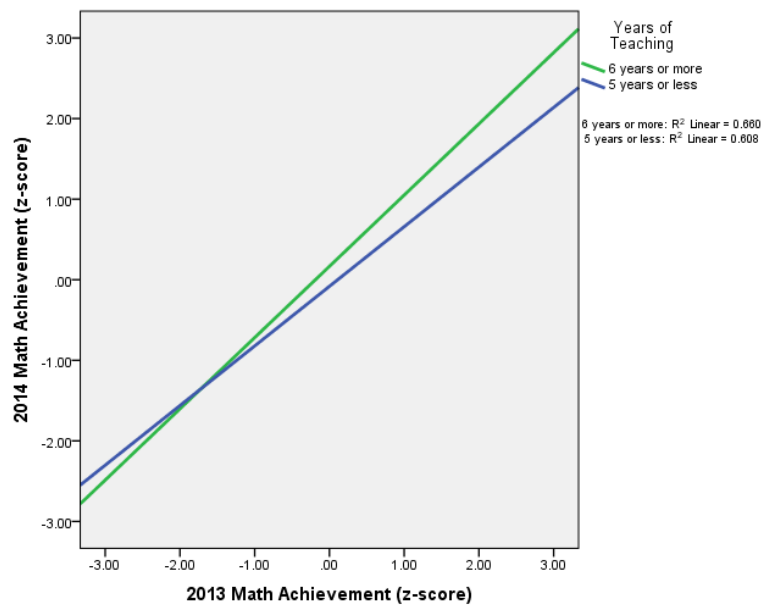


Figure 3. Moderating Effect of Teaching Experience on Math Achievement

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