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Danya M. Corkin
Rice University

Adem Ekmekci
Rice University

Anne Papakonstantinou
Rice University

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Antecedents of Teachers' Educational Beliefs about Mathematics and Mathematical Knowledge for Teaching among In-Service Teachers in High Poverty Urban Schools

Danya Corkin
Adem Ekmekci,
Anne Papakonstantinou
Rice University, United States of America

Abstract: This paper examines the antecedents of three types of educational beliefs about mathematics among 151 teachers predominantly working in high poverty schools. Studies across various countries have found that teachers in high poverty schools are less likely to enact instructional approaches that align with mathematics reform standards set by national and international organizations. Researchers contend that for instruction to change, educational beliefs about mathematics and teaching must change. Regression analyses indicated that mathematics-teaching experience was associated with teachers' self-efficacy for teaching mathematics at the onset of professional development and the number of mathematics college courses teachers had taken moderated their change in self-efficacy beliefs through professional development. Findings also indicated that epistemic beliefs about mathematics, which became more availing through professional development, were the strongest predictor of their mathematical knowledge for teaching. Results may inform professional development programs in promoting adaptive educational beliefs among teachers in high poverty schools.

Introduction

At a time when perceived teacher effectiveness in the United States is minimized to the measurement of students' achievement growth (Snyder & Dillow, 2011), and concerns over teacher quality have increased internationally (Leigh & Ryan, 2008; Rowe, 2003), it is imperative not to discount the role of teachers' educational beliefs on effective instruction (Akay & Boz, 2010; Pajares, 1992). Recognizing the importance of teachers' educational beliefs, several researchers have noted its significant role in both teacher education, including professional development, and in teacher quality (Enochs, Smith, Huinker, 2000; Pintrich, 1990; Wilkins, 2008). Consistent with this assertion, research has found an association between teachers' beliefs and teacher effectiveness (Stipek, Givvin, Salmon, & MacGyvers, 2001). For example, previous findings indicate that teacher' beliefs about their ability to successfully perform teaching-related tasks (self-efficacy) influences the type of instructional strategies they adopt and their instructional effectiveness (Guskey, 1988; Stipek et al., 2001).

Students who are most in need of effective instruction are economically disadvantaged students as it is well documented that they tend to perform not as well on achievement tests compared to their more affluent peers (e.g., Aikens & Barbarin, 2008). However, both national and international studies assessing teacher quality have consistently found that low-income students, unfortunately, receive less effective instruction on average compared to their higher income peers (e.g., Fuller, 1987, Max & Glazerman, 2014; Organisation for Economic Co-operation and Development [OECD], 2014). Further, studies examining instruction in high poverty schools across various countries have found that teachers within these schools are less likely to enact adaptive instructional approaches that align with mathematics reform standards set by national and international organizations such as the National Council for Teachers of Mathematics, Australian Education Systems Officials Committee, and OECD (Berry, Bol, & McKinney, 2009; Supovitz & Turner, 2000). For example, teachers in U.S. urban districts with a high percentage of economically disadvantaged students are more likely to ascribe to traditional teaching practices, which are also referred to as the "pedagogy of poverty"— instruction which is formulaic and routine with little emphasis on conceptual understanding and connection of material (Haberman, 1991, 2005). In order for teachers to adopt instructional practices that align with mathematics reform efforts, several researchers have contended that teachers' educational beliefs about mathematics teaching must change (Borko & Putnam, 1995; Haney, Czerniak, & Lumpe, 1996).

Identifying possible antecedents of educational beliefs among mathematics teachers who work in large urban school districts with a high percentage of low-income students may help inform teacher education programs, including professional development programs that work with this teacher population, to better promote adaptive educational beliefs about mathematics teaching. However, research specifically exploring mathematics background factors (e.g., mathematics college courses) that may influence teachers' educational beliefs about mathematics and the extent to which these beliefs change through teacher education programs is scant. Moreover, the limited studies that have examined mathematics background-related antecedents of teachers' educational beliefs have focused on teacher efficacy beliefs (e.g., Stevens, Aguirre-Munoz, Harris, Higgins, & Liu, 2013) with little emphasis on mathematics teachers' beliefs about the nature of mathematics knowledge. Thus, to uncover what characteristics contribute to teachers' educational beliefs, this study examined the extent to which mathematical background factors contribute to three types of teacher beliefs about mathematics among teachers predominantly working in large high-poverty urban districts. The three specific types of educational beliefs we examined were teachers' self-efficacy beliefs (Enochs et al., 2000), teachers' locus of control beliefs (Rose & Medway, 1981a), and teachers' epistemic beliefs about mathematics (Schoenfeld, 1989)—which are all linked to variations in instructional approaches (e.g., Stipek et al., 2001). We also investigated the extent to which these educational beliefs about mathematics teaching and learning change upon participation in an intensive professional development program focused on improving teachers' mathematical content and pedagogical knowledge.

While researchers acknowledge the importance of changing teachers' beliefs in order to influence their instruction to align with mathematics reform efforts (e.g., Gill, Ashton, & Algina, 2004), there also remains a need to understand which educational beliefs have the strongest association with knowledge about instruction that aligns with mathematics reform movements. This knowledge may inform professional development programs aimed at improving teacher instruction to determine which features of the program are in most need of emphasis. Minimal

research, however, has investigated the extent to which teachers' educational beliefs about mathematics predict their actual mathematical knowledge for teaching (MKT), which consists of both content knowledge and knowledge of how students learn (Ball, Thames, & Phelps, 2008). Several reasons justify investigating the effects of teachers' educational beliefs (which include motivational beliefs) on MKT. One, research in the area of student motivation has consistently found that self-efficacy beliefs in a particular domain influence achievement, which serves as a proxy for knowledge within that domain (Corkin, Yu, & Lindt, 2011; see Eccles & Wigfield [2002] for review). Two, recent findings indicate that teachers' self-concept beliefs in mathematics knowledge have a positive effect on MKT (Hill, 2010). Therefore, we also investigated the extent to which teachers' educational beliefs influence their MKT.

The rest of this literature review is structured as follows: First, we will provide a theoretical background for the three educational beliefs that are the focus of this study, and provide evidence linking each to adaptive instructional and student outcomes. Second, we will provide rationale for why teacher professional background factors may serve as antecedents of teacher beliefs. Third, we will discuss the possible role of professional development in changing teachers' educational beliefs. Finally, we will provide rationale for why each type of belief may relate to teachers' MKT.

Teachers' Educational Beliefs

Teachers' Self-efficacy

A central psychological mechanism within social cognitive theory (SCT) that plays a strong role in human agency is self-efficacy, which is defined as "a judgment of one's capability to accomplish a certain level of performance" (Bandura, 1986, p. 391). Within the teaching discipline, 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). Teachers' self-efficacy beliefs about mathematics teaching have been linked to their instructional approaches and their students' motivation and achievement (Anderson, Greene, & Loewen, 1988; Ross, 1992; Stipek et al., 2001). For example, previous studies have found that mathematics teachers who are less self-efficacious are more likely to ascribe to traditional mathematics classroom practices that emphasize procedures and rote memorization compared to their more self-efficacious peers, which in turn, has implications for student learning (Guskey, 1988; Stipek et al., 2001).

Seminal work attempting to conceptualize and operationalize teachers' self-efficacy beliefs stemmed from locus of control theory (Rotter, 1966). Measures informed by this theory assessed how much teachers attributed student outcomes to their own behavior (e.g., outcome expectancy, Enochs et al., 2000; Rose & Medway, 1981a). However, subsequent instruments assessing teachers' self-efficacy were developed to align with the definition of self-efficacy within a social-cognitive theoretical framework (Bandura, 1986; e.g., Personal Mathematics Teaching Efficacy, Enoch et al., 2000; Tschannen-Moran & Hoy, 2001). Thus, 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; Tschannen-Moran & Hoy, 2001). Proxies for these sources of teachers' self-efficacy examined in previous research include, but are not limited to, teaching experience, educational background in the

subject matter taught, and professional development experiences (Stevens et al., 2013; Swackhamer, Koellner, Basile, & Kimbrough, 2009; Wolters & Daugherty, 2007).

Teachers' Internal Locus of Control

Locus of control beliefs are considered a motivational dimension within attribution theory that capture whether a person ascribes the causal factors of personal behavior and the behavior of others as either internal or external (Rotter, 1966; Weiner, 1992). An internal locus of control is defined as one's belief that a particular outcome is dependent upon one's own behavior or permanent characteristics (Rotter, 1966). Within the teaching domain, 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, 1981a). Prior findings indicate that an internal locus of control among teachers positively predicts their job performance as well as their students' adaptive classroom behavior and academic achievement (Jeloudar & Lotfi-Goodarzi, 2012; Rose & Medway, 1981b; Sadowski, Blackwell, & Willard, 1985).

Several instruments have been developed to specifically measure teachers' locus of control beliefs (Rose & Medway, 1981a; Sadowski, Taylor, Woodward, Peacher, & Martin, 1982). Additional instruments have measured teachers' locus of control in the teacher efficacy research but have labeled this construct *outcome expectancy* and have cited Bandura's (1986) definition of outcome expectations as the conceptual premise behind this measure (e.g., Enochs et al., 2000; Gibson & Dembo, 1984). However, the manner in which outcome expectancy has been measured by these instruments is more aligned with a teachers' locus of control beliefs or the extent to which a teacher feels that he or she has control over students' achievement-related outcomes (Enochs et al., 2000). This differs from Bandura's (1986) definition of outcome expectancy, which does not focus on the extent to which a person feels a sense of personal control (or lack thereof) over a certain outcome or behavior (Rotter, 1966), but rather highlights the expected consequence a particular behavior will bring (Bandura, 1986). Consistent with this rationale, several researchers have noted that outcome expectancy measures in the teacher efficacy literature are actually assessing teachers' locus of control beliefs (Dellinger, Bobbett, Oliviar, & Ellett, 2008; Tschannen-Moran, Hoy, & Hoy, 1998; Tschannen-Moran & Hoy, 2001).

According to attribution theory, one's perception of whether a particular outcome can be attributed to internal or external factors is influenced by both the environment and personal characteristics (Weiner, 1994). Antecedents of locus of control that have been identified in previous research include socioeconomic status, race/ethnicity (Rotter, 1966), feedback from important others (e.g., teachers; Pintrich & Blumenfeld, 1985), and the difficulty of a task (Weiner, 1992). Research examining the antecedents of teachers' locus of control beliefs is limited, but because locus of control beliefs have been treated as outcome expectancies in the teacher efficacy literature, the antecedents examined in prior research are also proxies for Bandura's (1986) sources of self-efficacy as referenced in the previous section (Swackhamer et al., 2009).

Teachers' Epistemic Beliefs

Epistemic beliefs may be defined as an individual's beliefs about knowledge, which include one's beliefs about where knowledge comes from, what the essence of knowledge is, and

how one comes to know and justify beliefs (Hofer & Pintrich, 1997). Educational psychology researchers have conceptualized and measured epistemic beliefs as residing across two ends of a continuum (Schommer, 1994). On one end, individuals believe that knowledge is fixed, simple, certain, objective, and comes from a person of authority. The beliefs at this end are considered more naïve and have been classified by Muis (2004) as "non-availing" epistemic beliefs. Conversely, individuals classified as having sophisticated or "availing" epistemic beliefs view knowledge as evolving, complex, uncertain, subjective, and stemming from their own construction of knowledge (Schommer, 1994). Availing epistemic beliefs in mathematics have been found to be associated with positive motivational processes and academic achievement among students (see Muis [2004] for review).

Epistemic beliefs are posited to be influenced by both formal and informal educational experiences including teacher influences and engagement of learning and problem solving (Schommer, 1990). For example, researchers have proposed and found that teachers' instructional approaches can have an impact on students' epistemic beliefs about mathematics (e.g., Erickson, 1993; Schoenfeld, 1988). More specifically, teachers who directly tell students how to solve problems without presenting interconnections across concepts and who ask students to memorize formulas to complete assignments independently foster non-availing epistemic beliefs (Erickson, 1993). Conversely, teachers who enact constructivist approaches to instruction to facilitate learning by focusing on making mathematics meaningful through conceptual connections, and who enable students to become active participants in their own construction of knowledge through collaboration and group discussions foster availing epistemic beliefs (Erickson, 1993; Muis & Duffy, 2013).

While most of the studies conducted about the sources of epistemic beliefs have focused on students' beliefs, these studies may also provide an understanding of the antecedents of teachers' epistemic beliefs about their specific teaching-domain—in this case, mathematics. Because research has found that obtaining higher levels of education are associated with more availing epistemic beliefs (King, Wood, & Mines, 1990), it seems reasonable to assume that teachers with more advanced mathematical backgrounds would hold more availing epistemic beliefs about mathematics.

Antecedents of Teachers' Educational Beliefs

Teachers' Experience

The first antecedent that may be important to explore in relation to teachers' educational beliefs is their level of teaching experience. Previous research has identified important differences between beginning teachers and their more experienced counterparts in their level of content and pedagogical knowledge, class time utilization, classroom management, knowledge of students as learners, and their students' level of achievement (Harris & Sass, 2010; Hill, 2010; see Palmer, Stough, Burdenski, & Gonzales [2005] for review; Shulman, 1987). Additional studies have found specific qualitative differences in various instructional dimensions between novice and experienced teachers. For example, experienced teachers (compared to their less experienced counterparts) are more likely to respond to student performance cues with a wider variety of instructional strategies, implement a wider variety of instructional goals as a basis for classroom decisions, and devise more complex links between student performance cues and instructional responses (Fogarty, Wang, & Creek, 1983; Strahan, 1989). Given the evidence that

mathematics teachers with more years of experience tend to show stronger teaching performance, hold greater instructional knowledge, and have a longer history of mastery experiences (Tschannen-Moran & Hoy, 2007), there is justification for exploring the effects of mathematics teaching experience on mathematics teachers' educational beliefs.

Specific to teachers' self-efficacy beliefs, previous research examining the extent to which teaching experience is associated with teachers' self-efficacy has been mixed, perhaps because of the varying ways in which teachers' self-efficacy has been operationalized (Tschannen-Moran & Hoy, 2001). Early studies of teachers' self-efficacy beliefs either found no significant differences between less experienced teachers compared to their more experienced counterparts (Guskey, 1988), or lower levels of self-efficacy in several specific areas of instruction (e.g., involving parents in classroom instruction) among more experienced teachers compared to their less experience peers (De Mesquita & Drake, 1994). More recent studies examining the effect of teaching experience on self-efficacy indicate that early career teachers, on average, report lower levels of self-efficacy compared to their more experienced counterparts (Ross, Cousins, & Gadalla, 1996; Wolters & Daugherty, 2007).

Again, when it comes to the relation between teaching experience and teachers' internal locus of control, findings have not been consistent. Guskey (1988), using a scale measuring teachers' beliefs about their control of classroom successes and failures among elementary and secondary in-service teachers, found no relation between this measure and teacher experience. Another study was identified that examined antecedents of teachers' locus of control beliefs using Rose & Medway's (1981a) measure and found that teaching experience, along with age and student achievement growth, were significant predictors of teachers' locus of control among secondary vocational teachers (Hall, 1998).

There is some evidence to suggest that additional years of teaching experience are associated with more availing epistemic beliefs. One particular study used conceptual maps and interviews to investigate teachers' beliefs about the nature of the structure of knowledge and the source of knowledge (Strahan, 1989). In this study, researchers examined the complexity of conceptual maps depicting knowledge about middle school instruction among middle school teachers of varying levels of experience. Findings indicated that experienced teachers had a more interconnected conception of middle school instruction and conveyed through interviews more constructivist views of teaching compared to their novice peers (Strahan, 1989). These findings suggest that experienced teachers had developed more availing epistemic beliefs about middle school instruction with additional experience.

While recent findings suggest that associations exists between teaching experience and each of the three types of teachers' educational beliefs, studies have not examined domain-specific teaching experience and its association with domain-specific teaching self-efficacy. It seems critical to explore domain-specific teacher beliefs (in this case, mathematics) given that researchers contend that it is domain-specific beliefs that hinder change in teaching practices (e.g., Schoenfeld, 1992).

Teachers' Educational Background

A second antecedent that is relevant to investigate in relation to teachers' educational beliefs is their educational background in the subject matter they teach. It is well known that the educational background of U.S. teachers varies and in particular by grade level (NSB, 2010).

There is some evidence indicating that a strong background in the subject matter taught plays a critical role in effective teaching (see Rice [2003]). The majority of research that examines the influence of educational background in a teaching discipline, similar to other teacher attributes studied, explores its impact on student-related outcomes (Barry, 2010; Goe, 2007). However, the studies examining the relation between educational background in a given domain and teachers' educational beliefs are scarce and the limited studies that exist have produced mixed findings. Specifically, some studies have found that a strong educational background in the subject-matter taught is positively associated with adaptive educational beliefs (e.g., de Laat & Watters, 1995; Swackhamer et al., 2009; Walter, 2009), whereas several studies have found no significant relationship (e.g., Roberts, Busk, & Comerford, 2001; Stevens & Wenner, 1996; Swackhamer et al., 2009). Moreover, some studies have concluded that there is a negative relationship between the educational background of teachers and their educational beliefs (e.g. Isikoglu, Basturk, & Karaca, 2009; Stevens et al., 2013).

Specific to teachers' self-efficacy beliefs, a study conducted with primary teachers by de Laat and Watters (1995) showed that teachers with relatively strong backgrounds in science tended to have higher science teaching self-efficacy compared to their counterparts with weaker science backgrounds. Conversely, Stevens et al. (2013) found that middle school mathematics teachers with a greater mathematics background had lower levels of self-efficacy for instruction. Another study that investigated the relation between middle school science and mathematics teachers' beliefs and their educational background in their respective domain found no significant difference in teaching self-efficacy beliefs between teachers who took more content courses compared to those who took fewer (Swackhamer et al., 2009).

Results from studies examining teachers' educational background in relation to their locus of control beliefs have also been mixed. Among the studies that explored the association between educational background and internal locus of control, Stevens and Wenner (1996) did not find a significant correlation between the number of high school and college science and mathematics courses taken and internal locus of control for both primary science and mathematics teacher candidates. In contrast, Swackhamer et al. (2009) found that middle school science and mathematics teachers who had four or more content hours of college level coursework had statistically significant higher levels of internal locus of control compared to their peers who had fewer than four hours of college content hours.

Educational background has also been associated with epistemic beliefs. Specifically, having higher levels of education is associated with higher levels of availing epistemic beliefs (King et al, 1990). Perhaps this relationship is not surprising given that as one gains more knowledge about a subject it is reasonable to assume that their views of knowledge about that subject also change and become more refined. For example, taking more advanced mathematics courses may change one's perspective about the depth of mathematics, and in turn, may change one's epistemic beliefs about mathematics. Mathematics teachers go through different educational routes that vary by the number and level of mathematics courses required. Therefore, these varying education routes may lead to differences in epistemic beliefs. Consistent with this notion, Schmidt et al. (2007) conducted a national study comparing three different mathematics teacher-preparation programs, where the level of mathematics taken in each program differed from each other, and found significant differences between the three programs in terms of the way teacher candidates perceived the nature of mathematics knowledge. These findings suggest that the level of education in a particular domain plays a role in the development of teachers' epistemic beliefs (Schommer, 1998).

Overall, the findings seem inconsistent in terms of the way educational background relates to educational beliefs. There may be several reasons for varied results including different proxies used as a measure of academic background in a given discipline, different facets of educational beliefs used as outcomes, and varying levels of discipline specificity (see Rice, 2003). However, these varying findings may also suggest that the educational background in a particular subject matter might play a role in some types of educational beliefs but not in others (e.g., Swackhamer et al., 2009). The next section will discuss how professional development aimed at developing teachers' content and pedagogical knowledge may be associated with changes in teachers' educational beliefs about mathematics.

Professional Development focused on Mathematics Content and Pedagogical Knowledge

Professional development of teachers has been identified as one of the key factors of improving public education (Borko, 2004). Professional development focusing specifically on content and pedagogical knowledge has been proven to increase teachers' effectiveness (Desimone, 2009). Studies have shown that professional development programs for teachers can have a positive and significant impact on teachers' knowledge, skills, beliefs, attitudes, and instructional practices with consideration of contextual influences such as school leadership and policy, curriculum, and the characteristics of students (Ekmekci, Corkin, & Papakonstantinou, 2015; Borko 2004; Garet, Porter, Desimone, Birman, & Yoon, 2001; Desimone, 2009; Hill & Ball, 2004; Timperley, Wilson, Barrar, & Fung, 2007). A study synthesizing the effects of teacher professional learning and development across the world indicated that it has a positive impact on student outcomes (Timperley et al., 2007). Moreover, this study concluded that teachers' knowledge and beliefs about what is important to teach and how to teach it were among the key factors for effective teaching (Timperley et al., 2007).

As mentioned earlier, mathematics teacher preparation and development programs consider teacher knowledge and beliefs as strongly linked (e.g., Desimone, 2009; Loucks-Horsley, Swan & Swain, 2010; Stiles, Mundry, Love, & Hewson, 2010). In addition, since change in knowledge does not occur in isolation, (Loucks-Horsley et al., 2010), one could conceivably argue that as knowledge changes, beliefs also change, and vice versa. Clark et al. (2014) found a significant relationship between mathematics teachers' beliefs and mathematical knowledge. Therefore, professional development of teachers that focuses on developing teachers' knowledge and skills may also potentially change teachers' beliefs as it influences their content and pedagogical content knowledge.

Teachers' Educational Beliefs and Mathematical Knowledge for Teaching

Teachers' beliefs and knowledge are closely related. Thus, distinguishing one from the other is a difficult task (Pajares, 1992). Hill, Ball, and Schilling (2008) refer to teacher knowledge in mathematics as mathematical knowledge for teaching (MKT). They define MKT as "*the mathematical knowledge that teachers use in classrooms to produce instruction and student growth"* (Hill et al., 2008, p. 374). MKT encompasses not only knowledge about content but also knowledge about students' ideas, knowledge, and conceptual understanding of material. The MKT model comprises of subject matter knowledge and pedagogical content knowledge

(PCK) in mathematics. Subject matter knowledge can be described as pure mathematical knowledge that teachers use in ways that are common with how other professionals use mathematics. PCK in mathematics includes *knowledge of content and students*, *knowledge of content and teaching*, and *knowledge of curriculum* (Hill et al., 2008).

This paper relies on the assumption that teachers' beliefs and knowledge complement each other but are distinct constructs (Loucks-Horsley et al., 2010; Pajares, 1992). There are different schools of thought in the literature about situating teachers' beliefs with respect to their knowledge (Clark et al., 2014; Kagan, 1992; Van Driel, Verloop, & de Vos, 1998). Regardless of how beliefs are situated and operationalized in teachers' knowledge base, it is unequivocally agreed upon that teachers' beliefs are important and related to teachers' knowledge (Loucks-Horsley et al., 2010). For example, according to Van Driel et al. (1998), teachers' professional knowledge entails beliefs about various aspects of teaching and learning such as the content, pedagogy, students, and curriculum. Moreover, teacher beliefs about their ability to enact effective teaching methods for specific teaching goals has been found to be associated with PCK and mathematical knowledge (Clark et al., 2014; see Park & Oliver [2008] for a review).

While it seems clear that a relation exists between beliefs and knowledge, the directionality of this relation is uncertain. However, consistent with previous achievement motivation research that has examined students' domain-specific beliefs (e.g., self-efficacy) as antecedents of their performance on domain-specific knowledge assessments (e.g., Simpkins, Davis-Kean, & Eccles, 2006), this study will examine teachers' beliefs about mathematics teaching and learning as antecedents of their performance on a mathematical knowledge for teaching (MKT) assessment. This sequence of beliefs and knowledge is also consistent with methodological approaches in previous mathematics education research (e.g., Hill, 2010).

Based on prior research, it is reasonable to argue that teachers' educational beliefs about mathematics that are considered adaptive would positively correlate with their MKT. In other words, if teachers have, for example, availing epistemic beliefs about mathematics and high self-efficacy in teaching mathematics, they would also have higher levels of MKT. However, the relation between specific types of beliefs (e.g., epistemic beliefs) and knowledge, especially MKT, needs to be further explored (see Briley, 2012).

Given the need to explore discipline-specific antecedents of several types of teachers' educational beliefs about mathematics teaching and learning and to differentiate the varying influence these beliefs have on teachers' MKT, the following research questions guided this study.

- To what extent did mathematics background variables (years of teaching mathematics and college hours in mathematics) predict teachers' self-efficacy for teaching mathematics, internal locus of control, and epistemic beliefs about mathematics at the onset of a professional development program and on the change in these beliefs through professional development?
- To what extent did teachers' educational beliefs change during the three-week program?
- To what extent did teachers' educational beliefs (self-efficacy, internal locus of control, and epistemic beliefs) predict MKT at the completion of the 3-week professional development program?

Method
Procedure

In this study, we surveyed K-12 in-service teachers who participated in a three-week professional development intervention aimed at improving teachers' content and pedagogical knowledge. The two cohorts of teachers who were included in this study participated in the professional development in one of two summers: 2013 and 2014. Summer campus programs (SCP) were 84 contact hours (3 weeks, 4 days a week, and 7 hours a day) and aimed to provide a rigorous mathematics instruction program for K-12 teachers, who attended one of four classes based on the grade level of their teaching assignments for the subsequent academic year. These four classes were elementary (K-3), intermediate (4-6), middle school (7-8), and high school (9-12).

The two SCPs had different content foci. The mathematical content focus of the 2013 SCP (first cohort) was on: (a) numbers, operations, and quantitative reasoning; and (b) patterns, relationships, and algebraic reasoning. The content focus of the 2014 SCP (second cohort) was on: (a) geometry, spatial sense, and measurement; and (b) data analysis, statistics, and probability. Mathematics topics covered in SCPs aimed at enhancing and transcending traditional classroom mathematics instruction by including the incorporation of technology and manipulatives in the classroom. Both SCPs emphasized the following research-based constructs: active learning approaches (e.g., Swiderski, 2011), motivation, applications, problem solving (e.g., Pajares, & Graham, 1999), and concept-based learning activities (e.g., Erickson, 2007). Specifically, teachers undertook the role of students and actively explored important mathematics content and discussed the pedagogical nature of the educational activities they enacted. In addition, teachers had curriculum development experiences through "lesson plan" activities and assignments.

To complement the classroom experience, several special events were organized to bring together participants from all of the classes to foster vertical grade-level interactions among teachers. These events included several colloquia and a K-12 mathematics summit on a research university campus. Colloquia included research-based lectures by distinguished university-level visiting mathematics educators. During the mathematics summit, participants were placed in groups of four with each group containing one participant from each of the four classes. These groups then met throughout the summer as all participants read and studied books about mathematics teaching and learning in the 21st century. In addition, all classes participated in exploring the integration of mathematics with children's literature and art.

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 about mathematics. Teachers also took a 30-minute test measuring their MKT on the last day of the SCP.

Participants

Representing several urban school districts in the southwestern U.S., 151 K-12 mathematics teachers participated in the study. The majority of these teachers (85%) were teaching in high poverty schools, which according to Olson and Jerald (1998) is a school where at least 50% of enrolled students qualify for free and/or reduced lunch. In terms of gender, 118 (78%) were females and 33 (22%) were male. The ethnic make-up of the sample was 25%

White, 39% African American, 26% Hispanic, 8% Asian, and 2% other. Teachers, on average, had taken 21 college mathematics hours and had 3.5 years of mathematics teaching experience. The grade-level breakdown was as follows: 42 teachers taught elementary (grades K-3); 35 taught intermediate (grades 4-6); 38 taught middle school (grades 7-8); and 36 taught high school (grades 9-12).

Measures

We surveyed teachers before and after a 3-week professional development program. The survey comprised of several sections including demographic information, mathematics background, and a battery of scales measuring three constructs: teachers' self-efficacy, internal locus of control, and non-availing epistemic beliefs. Item responses were on a 5-point Likert scale ranging from strongly disagree (1) to strongly agree (5). Higher scores for first two constructs showed beliefs that are more positive whereas a lower score on the last construct was associated with beliefs that are more positive since the items measured "non-availing" epistemic beliefs. More details about the scales are given below. We also measured teachers' MKT.

Self-efficacy Scale

The self-efficacy scale consisted of 13 items to measure the extent to which teachers believed they could successfully perform teaching-related tasks in mathematics instruction. The items were adapted from the Mathematics Teaching Efficacy Beliefs Instrument (MTEBI) (Enochs et al., 2000). The reliability analysis of this scale produced a Cronbach's alpha of .85 ($n = 151$). An example of an item is as follows: "I understand mathematics concepts well enough to be effective in teaching mathematics." Higher scores in items represent a higher level of presence of self-efficacy in mathematics teaching (beliefs that are more positive.

Internal Locus of Control Scale

Because the instrument that has been used in this study aligns more with Rotter's (1966) locus of control, and more specifically with Rose & Medway's (1981a) teachers' locus of control, we have re-labeled the outcome expectancy construct measured by the MTEBI as internal locus of control given that questions ask to what extent teachers feel teaching behaviors contribute to student success. The internal locus of control scale consisted of 8 items to measure the extent to which teachers attributed student achievement to themselves or their teaching. The items were adapted from the Mathematics Teaching Outcome Expectancy subscale of MTEBI instrument (Enochs et al., 2000). The reliability analysis of this scale produced a Cronbach's alpha of .75 ($n = 151$). An example of an item is as follows: "The inadequacy of a student's mathematics background can be overcome by good teaching." Higher scores in items showed a higher presence of an internal locus of control (beliefs that are more positive).

Non-availing Epistemic Beliefs Scale

The epistemic beliefs scale consisted of 7 items to measure teachers' non-availing beliefs about mathematics, such as the certainty of mathematics knowledge, the source of mathematics knowledge, and the structure of mathematics knowledge. The items were adapted from the Problem-Solving Project Questionnaire (Schoenfeld, 1989). The reliability analysis of this scale

produced a Cronbach's alpha of .72 (n = 151). An example of an item is as follows: "To solve most mathematics problems you have to be taught the correct procedure." Lower scores in items showed a higher presence of availing epistemic beliefs (more positive beliefs) since items represent a "non-availing" epistemic belief.

Mathematical Knowledge for Teaching Scale

Teachers' mathematical knowledge for teaching was measured by the Learning Mathematics for Teaching (LMT) instrument, which is valid and reliable (Hill, Schilling, & Ball, 2004). The LMT was administered at the completion of the 3-week summer professional development program. Two LMT instruments were used to measure teachers' MKT. K-6 teachers (40) took El NCOP 2008 (Form B) while grades 7-12 teachers (40) took MS PFA 2007 (Form B). El NCOP instrument had 29 multiple-choice items covering numbers concepts and operations topics. MS PFA instrument had 33 multiple-choice items covering patterns, functions, and algebra topics. The total IRT scaled z-scores on the instruments were calculated. Reliability analyses produced Cronbach's alphas of .86 (n = 40) and .85 (n = 40) for El CNOP and MS PFA, respectively.

Results

Antecedents of Teachers' Educational Beliefs

We conducted six two-step hierarchical regression analyses to investigate the predictive value of years of mathematics teaching and college mathematics hours on the three belief constructs and on the change in these three constructs, controlling for gender and ethnicity. We controlled for gender and ethnicity because previous research has noted that gendered and racialized experiences can also shape teachers' beliefs (c.f. Clark et al., 2014). Table 1 shows means, standard deviations, and correlation coefficients between all background variables and teachers' beliefs and the change in beliefs. There was no significant relationship between gender and belief variables, indicating that gender is not a good predictor of adaptive beliefs about learning and teaching mathematics. However, race/ethnicity had a modest but statistically significant association with epistemic beliefs. Black teachers were more likely, on average, to have higher levels of non-availing epistemic beliefs compared to other ethnicities ($r = .20$, $p < .05$). In terms of professional background variables, years of mathematics teaching was positively and significantly related to self-efficacy in teaching mathematics ($r = .21$, $p < .01$), indicating that experienced teachers felt more self-efficacious in teaching mathematics. College mathematics hours was negatively associated with the change in self-efficacy beliefs in teaching mathematics ($r = -.19$ $p < .05$), indicating that teachers' self-efficacy beliefs in teaching mathematics grew more during the professional development for those who had fewer college mathematics hours. Teachers' scores on the three belief measures were negatively and significantly associated with growth in those measures (with r's ranging from -.33 to -.56, $p < .01$ for all). This finding is not surprising because teachers who began with higher scores on each belief scale had less room for improvement. This finding also implies that teachers who had less adaptive beliefs benefitted more from the professional development.

In the six two-step regressions, the first step included gender and racial/ethnic variables while the second step included professional background variables. Table 2 provides statistical

information about the significance of key variables controlling for other potentially correlated factors and the amount of total variation in beliefs explained by these key variables. In

the regression predicting mathematics teaching self-efficacy beliefs, the model in Step 2 was statistically significant ($F(6, 141) = 2.35$, $p < .05$), explaining about 10% of the variation in self-efficacy beliefs after controlling for gender and ethnicity. Specifically, years of mathematics teaching was a significant indicator of self-efficacy beliefs in teaching mathematics at the onset of the PD program ($\beta = 0.21$, $p < .05$). This finding implies that one standard deviation increase in mathematics teaching years is associated with a .21 standard deviation increase in self-efficacy beliefs for mathematics teaching.

In the regression predicting non-availing epistemic beliefs in mathematics, the model in Step 1 was statistically significant ($F(4, 143) = 3.75$, $p < .01$). This model explained about 10% of the variation in non-availing epistemic beliefs. In this model, ethnicity was a significant indicator of epistemic beliefs at the onset of the professional development program.

Although Table 2 shows several other significant coefficients, the regression models that included those coefficients did not significantly account for the variation in belief variables. These regression analyses produced significant associations between college mathematics hours and the change in self-efficacy beliefs (negatively associated), between being from an “other” ethnic background and self-efficacy beliefs, between being Hispanic and beliefs about internal locus of control, and between being Hispanic and epistemic beliefs. However, the models that produced these associations were not statistically significant.

Change in Teachers’ Beliefs in Professional Development

We conducted paired-samples *t*-tests on the three belief measures to investigate whether teachers showed growth in their beliefs about teaching and learning mathematics upon completion of a professional development that focused primarily on pedagogical content knowledge. As Table 3 shows, overall, there were significant changes in teachers’ scores on the three belief measures from pre- to post-survey ($p < .01$). Effect sizes of the changes were moderate, with Cohen’s *d*’s ranging from 0.46 to 0.64. On average, teachers’ scores in self-efficacy beliefs in teaching mathematics and in beliefs about their internal locus of control increased by 5.5% and 5.3 % (0.22 and 0.21 points), respectively, while their scores in non-availing epistemic beliefs decreased by 7% (0.28 points).

We, then, divided teachers into two groups (grades K-6 and grades 7-12) to see if there was any association between grade level and beliefs about teaching and learning mathematics. Since previous research indicates that elementary teachers have less mathematics background compared to higher grades (National Science Board, 2010), grade level might also play a role in teachers’ adaptive beliefs about mathematics (e.g., Wolters & Daugherty, 2007). We conducted independent-samples *t*-tests to compare the two groups of teachers. Initially, there was no significant difference between the two groups on the pre-survey ($p > .05$; not shown). From pre- to post-survey, K-6th grade teachers increased their self-efficacy beliefs scores by about 5.5% (0.22 out of 4 points) more than 7th-12th grade mathematics teachers ($p < .01$ with a moderate effect size of .55; see Table 4).

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11
1. Gender (0 = F, 1 = M)	.22	.41	---										
2. Black (Non-Hispanic)	.38	.49	-.11	---									
3. Hispanic	.26	.44	.10	-.47**	---								
4. Other	.10	.30	-.12	-.26**	-.20*	---							
5. Years of Math Teaching	3.52	4.06	-.05	.09	-.04	-.03	---						
6. Math College Hours	21.35	15.83	.10	-.04	.02	.05	.00	---					
7. Self-efficacy in Teaching Math	4.04	0.49	.00	.11	-.10	.14	.21**	.07	---				
8. Internal Locus of Control	3.51	0.48	.02	.02	.02	.00	.07	-.06	.11	---			
9. Non-availing Epistemic Beliefs	2.25	0.52	-.07	.20*	.04	.05	.06	-.04	-.20*	-.08	---		
10. Δ Self-efficacy in Teaching Math	0.22	0.42	.00	-.08	.08	-.05	-.08	-.19*	-.56**	.03	.09	---	
11. Δ Internal Locus of Control	0.22	0.46	-.02	.04	.14	-.04	.00	.02	-.08	-.33**	.09	.21**	---
12. Δ Non-availing Epistemic Beliefs	-0.28	0.44	.04	.02	-.16	-.06	.07	.12	.05	-.12	-.41**	-.11	.01

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

Table 1: Means, standard deviations, and Pearson correlations among the main variables for antecedents of teachers' beliefs

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						
Gender[1]	0.04	0.03	-0.03	-0.01	-0.02	0.03
Black (Non-Hispanic)[2]	0.16	0.05	0.36**	-0.09	0.14	-0.14
Hispanic[2]	0.02	0.05	0.25*	0.03	0.21*	-0.26*
Other[2, 3]	0.19*	0.03	0.19*	-0.06	0.03	-0.15
Step 2						
Years of Math Teaching	0.21*	0.07	0.04	-0.07	0.00	0.07
Math College Hours	0.06	-0.06	-0.04	-0.19*	0.02	0.12

Notes. β: Standardized regression coefficient. $N = 148$. $^{*}p < .05$. $^{**}p < .01$. [1] Reference category: Male. [2] Reference category: White. [3] Other includes Asian. [a] Step 1: $R^2 = .05$, $p > .05$; Step 2: $\Delta R^2 = .05$, $p < .05$. [b] Step 1: $R^2 = .00$, $p > .05$; Step 2: $\Delta R^2 = .01$, $p > .05$. [c] Step 1: $R^2 = .10$, $p < .01$; Step2: $\Delta R^2 = .00$, $p > .05$. [d] Step 1: $R^2 = .02$, $p > .05$; Step2: $\Delta R^2 = .04$, $p > .05$. [e] Step 1: $R^2 = .03$, $p > .05$; Step2: $\Delta R^2 = .00$, $p > .05$. [f] Step 1: $R^2 = .05$, $p > .05$; Step2: $\Delta R^2 = .02$, $p > .05$.

Table 2: Summary of hierarchical regression analyses predicting teachers' beliefs

Survey	**N**	**Paired Differences** Mean Gain (post-pre)	**S.D.**	***t*-value**	**Cohen's *d***
Self-efficacy in Teaching Math	151	0.22	0.42	6.40**	.52
Internal Locus of Control	151	0.21	0.45	5.71**	.46
Non-availing Epistemic Beliefs	151	-0.28	0.45	-7.86**	.64

Notes. $^{**}p < .01$.

Table 3: Paired-samples *t*-test results on measures of teachers' educational beliefs before and after PD

Survey	**N**		**Mean Gain (post-pre)**		**S.D.**		***t*-value (K-6 vs 7-12)**	**Cohen's *d***
	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**	0.551
Δ Internal Locus of Control	77	74	0.22	0.21	0.42	0.49	.018	-
Δ Non-availing Epistemic Beliefs	77	74	-0.34	-0.27	0.47	0.43	2.566	-

Notes. $^{**}p < .01$.

Table 4: Independent-samples *t*-test results for comparing change in beliefs between grade levels

Teachers' Beliefs and MKT

We conducted a hierarchical regression analysis (two-step) to investigate the predictive value of teachers' educational beliefs on their MKT. This set of regressions differs from the first set of regressions in several ways. In this second regression, MKT was included as the outcome variable and the three belief constructs were entered as predictors rather than dependent variables. In addition, grade level is included in this set of regressions. Although it was of interest, the reason that the grade level was not included in the first set of regressions was because grade level was significantly associated with the number of mathematics college courses participating teachers had taken. Thus, we excluded grade level from the regression analysis to avoid collinearity issues with college mathematics hours and because mathematics background was the focus of this study. Lastly, the changes in beliefs over time are not included in the second regression.

Correlation analysis was conducted for initial screening of the relationships among the main variables in the regressions. Table 5 shows means, standard deviations, and correlation coefficients between all background variables, teachers' educational beliefs, and their scores on the LMT. Neither gender nor grade level was a significant predictor of MKT. However, race/ethnicity had a statistically significant association with LMT scores. Specifically, Black teachers were found to have lower LMT scores compared to teachers from other racial/ethnic backgrounds ($r = -.46$, $p < .01$). When we examined the association of educational beliefs with LMT scores, only non-availing epistemic beliefs had a strong relation to LMT scores ($r = -.34$, $p < .01$), suggesting that more availing beliefs were associated with higher LMT scores.

In the regression analysis, the first step included the grade level, gender, and ethnicity as control variables while the second step included the main predictors: professional background variables and educational belief variables. Table 6 provides statistical information about the significance of key variables. In the regression predicting LMT scores, the models in Step 1 and Step 2 were statistically significant ($F(7, 70) = 4.14$, $p <.01$; $F(10, 67) = 4.08$, $p <.01$, respectively). The two models together explained about 38% of the variation in LMT score ($p < .05$), after controlling for grade level, gender, and ethnicity. Specifically, Black teachers had lower LMT scores compared to White teachers ($\beta = -0.42$, $p < .01$). In addition, having non-availing epistemic beliefs was a significant negative predictor of LMT scores ($\beta = -0.31$, $p < .01$).

Discussion

This study contributes to the teacher education literature in several ways. First, this study expands our knowledge of which teacher educational beliefs about mathematics are most closely associated with mathematics teaching experience and mathematics content background. Second, it informs us about the extent to which these antecedents influence the development of adaptive educational beliefs in a professional development program. Perhaps these findings will encourage teacher educators to identify which teachers would benefit most from particular aspects of a professional development program by assessing these mathematical background characteristics. Third, this study highlights the integral role of teachers' epistemic beliefs about their teaching domain—in this case mathematics—in their knowledge of teaching mathematics.

Variable	*M*	*SD*	*1*	2	3	4	5	6	7	8	9	10	11
1. Grade Level (0 = Elem., 1 = Middle and High)	.50	.50	---										
2. Gender (0 = Female, 1 = Male)	.24	.43	*0.15*	---									
3. Black (Non-Hispanic)	.38	.49	*-0.05*	-0.08	---								
4. Hispanic	.26	.44	*0.00*	0.08	-0.46**	---							
5. Other	.06	.25	*-0.05*	-0.15	-0.21	-0.15	---						
6. Years of Math Teaching	3.34	3.74	*-0.16*	-0.12	0.04	-0.09	0.13	---					
7. Math College Hours	22.35	16.64	*0.40***	0.12	-0.06	0.19	-0.09	-0.01	---				
8. Self-efficacy in Teaching Math (Post)	4.24	0.44	*-0.18*	0.05	0.05	0.01	0.10	0.28*	-0.15	---			
9. Internal Locus of Control(Post)	3.70	0.53	*-0.18*	-0.02	0.05	0.21	0.05	0.15	-0.09	0.29**	---		
10. Non-availing Epistemic Beliefs (Post)	2.05	0.51	*0.03*	-0.03	0.17	-0.05	0.03	0.09	0.15	-0.29*	-0.02	---	
11. LMT	0.21	0.95	*0.22*	0.12	-0.46**	0.06	0.20	0.03	0.11	0.03	-0.10	-0.34**	---

Notes. $N = 78$; $^{*}p < .05$. $^{**}p < .01$.

Table 5: Means, standard deviations, and Pearson correlations among the main variables for outcomes of teachers' beliefs

Variable	LMT
	β
Step 1	
Grade Level (0 = Elementary, 1 = Middle and High)	0.17
Gender[1]	0.09
Black (Non-Hispanic)[2]	-0.42^{**}
Hispanic[2]	-0.14
Other[2, 3]	0.12
Step 2	
Years of Math Teaching	0.10
Math College Hours	0.08
Self-efficacy Beliefs	-0.04
Internal Locus of Control Beliefs	-0.02
Non-availing Epistemic Beliefs	-0.31^{**}

Notes. β indicates standardized regression coefficient. $N = 78$. $^{*}p < .05$. $^{**}p < .01$.
[1]Reference category: Male. [2] Reference category: White. [3] Other includes Asian.
Step 1: $R^2 = .29$, $p < .01$; Step 2: $\Delta R^2 = .09$, $p < .05$.

Table 6: Summary of hierarchical regression analyses predicting teachers' MKT

Antecedents of Teachers' Educational Beliefs

In terms of antecedents of teachers' educational beliefs, years of experience in mathematics teaching emerged as positively associated with self-efficacy for teaching mathematics at the onset of the professional development program. This finding is consistent with previous research that examined self-efficacy for instruction among teachers of various disciplines (Wolters & Daugherty, 2007). There are several reasons why teachers with additional years of experience teaching mathematics are more likely to have higher self-efficacy compared to their more novice peers. First, teachers who have taught mathematics for a longer period have had more opportunities to participate in professional development, which according to previous research enhances teachers' self-efficacy beliefs (Stevens et al., 2013). Related to the additional professional development opportunities, teachers who have taught for numerous years also have more opportunities to learn vicariously through mastery models (a source of self-efficacy; Bandura, 1986) by observing expert teachers. Observing expert teachers is considered an "active learning" feature of effective professional development programs (Desimone, 2009). Finally, more experienced teachers have had more direct teaching experience, and therefore, have had more opportunities to develop their teaching skills in a classroom environment, which, in turn, increases their confidence for teaching. This rationale aligns with the idea that veteran teachers have a greater history of enactive mastery experiences (which increases self-efficacy) compared to newer teachers (Bandura, 1986; Tschannen-Moran & Hoy, 2007).

While the number of years teaching mathematics was positively associated with self-efficacy at the onset of the professional development program, this teacher background variable did not predict the change in teaching self-efficacy beliefs by the end of the professional development program. However, teachers' educational background—specifically, the number of

mathematics hours taken at college—moderated the extent to which teachers enhance their self-efficacy in teaching mathematics throughout a professional development program. In other words, teachers who entered the program with fewer college mathematics hours were more likely to experience greater growth in their mathematics teaching self-efficacy compared to their counterparts who had more college mathematics hours.

Current findings contradict results from Stevens et al. (2013) who found that teachers with greater mathematical background (teacher who had taken a course beyond college algebra) had lower self-efficacy beliefs on three facets of teaching self-efficacy at the onset of professional development and experienced greater self-efficacy growth in professional development compared to their counterparts with less mathematical background. There are several reasons why our findings are inconsistent with Stevens et al.'s (2013) findings. First, Stevens et al.'s (2013) measure of self-efficacy was more general in the sense that questions were not framed around mathematics instruction specifically. Second, to assess mathematical background, we used the number of college mathematics hours teachers had taken, which varied considerably more than Stevens et al.'s (2013) measure. Our measure is a more precise representation of the quantity of mathematics that teachers were exposed to and may be a better indicator of teachers' own self-efficacy for mathematics given that motivation studies have found that high self-efficacy in a particular domain is associated with taking a greater number of courses in that domain (e.g. Updegraff, Eccles, Barber, & O'Brien, 1996). Furthermore, in the teacher education literature, mathematics self-efficacy has been found to relate positively to mathematics teaching self-efficacy (Briley, 2012). Because self-efficacy in a domain is related to performance in that domain (Bandura, 1986), our measure may be serving as proxy for gauging teachers' actual content knowledge. While content knowledge is only a portion of what constitutes effective mathematics teaching (Ball, Hill, & Bass, 2005), it may not have accounted for enough variation in mathematics teacher's confidence levels for teaching mathematics to render it significant at the onset of this professional development program. Perhaps if mathematical background measures included a composite metric representing both mathematics content and pedagogical courses, significant associations between mathematical-related courses and mathematics teaching self-efficacy would emerge. Nevertheless, teachers who had taken a greater number of mathematics courses did experience significantly less growth in mathematics teaching self-efficacy compared to their counterparts who had taken fewer courses. This finding suggests that professional development programs that focus on content knowledge may be most beneficial to teachers who enter the program with less knowledge in mathematics in terms of developing their confidence to teach the subject. Perhaps this will inform professional development programs to hone in on emphasizing content knowledge for those teachers with less exposure to mathematics. Programs should also gauge the number of methods courses teachers have taken so that professional development for teachers lacking a background in effective pedagogy emphasizes mathematics pedagogy over pure mathematics content.

The mathematics background variables examined did not emerge as significant predictors of teachers' internal locus of control or epistemic beliefs. This finding is not surprising given that theoretical support is not as strong for assuming that teaching experience and educational background would emerge as antecedents of these beliefs. The premise behind examining these antecedents for locus of control have been informed by social-cognitive theory (Bandura, 1986), despite the fact that inconsistencies have existed between the theoretical conceptions of outcome expectancies (social-cognitive construct) and the respective measures that align with Rotter's (1966) locus of control. Rose and Medway (1981a) suggest that teachers' colleagues and

administrators may play a role in their locus of control beliefs. For example, while teachers' personal characteristics may influence the extent to which they feel control over their students' academic achievement, the current culture of high-stakes assessment—where tests are sometimes provided from external sources that assess competencies that do not always align with the teachers' instruction—may result in teachers feeling little control of student outcomes (Shepard, 2000). Thus, the variation in which teachers experience this culture of assessment and their respective sense of control may be better accounted for by the amount of instructional autonomy provided to them by school leaders and administration.

Reasons for why teacher experience and mathematics background did not significantly relate to teachers' epistemic beliefs may have to do with the granularity of these measures in terms of assessing the qualitative aspects of prior formal and informal learning experiences. While taking more mathematics courses and having more experiences teaching mathematics provide additional avenues for developing availing epistemic beliefs, prior research has indicated that specific features of these experiences are what trigger change in epistemic beliefs. For example, Gill et al. (2004) performed an intervention with pre-service teachers that involved having them read text that: 1) refuted procedural (traditional) instruction and 2) promoted constructivist instructional strategies by providing scientific evidence of their effectiveness. They found that teachers who received the intervention experienced greater change in their epistemic beliefs and had more availing epistemic beliefs compared to teachers who did not read text refuting their procedural beliefs and approaches (Gill et al., 2004). Thus, variations in epistemic beliefs between teachers may have more to do with the extent to which their educational experiences challenge conventional thinking, which may not necessarily occur with additional exposure to education related to a particular subject matter.

Another significant finding that emerged when examining the predictors of teachers' beliefs and change in beliefs was that ethnic-minority teachers were more likely to have non-availing epistemic beliefs about mathematics compared to their White counterparts at the onset of the professional development program. One explanation for why ethnic-minority teachers are more likely to hold non-availing epistemic beliefs may have to do with their school environment. Haberman (1995) has noted that in high poverty urban schools mathematics instruction centers on memorization and simple procedure, which stands in stark contrast with constructivist approaches that align with beliefs about mathematics knowledge that is complex, interconnected, and constructed. Upon further examination of the school demographics for which participating teachers taught, it seems that while the majority of teachers came from schools with a large percentage of students from low socioeconomic backgrounds, it appears that Black teachers were more likely to be employed at schools with higher mobility rates. High mobility rates have been found to be an indicator of more extreme levels of poverty given that high rates are associated with a larger population of children of migrant workers and a larger population of homeless children (*Education Week*, 2004; Rumberger & Larson, 1998). In addition, school demographic information of participating teachers also indicated that the average percent of economically disadvantaged students in the schools where White teacher participants taught was significantly lower compared to the schools where their ethnic-minority counterparts taught. Thus, ethnic-minority teachers are possibly more likely to find themselves in situations where it becomes more difficult to incorporate non-traditional, constructivist approaches in their instruction (Haberman, 1991), and in turn, this type of environment may influence their epistemic beliefs about mathematics. This finding is consistent with previous research that has found differences between teachers at low socioeconomic status schools versus teachers at high socioeconomic

schools in terms of the extent to which they emphasize facts and procedures in their mathematics instruction (Clark et al., 2014; Minor, Desimone, Phillips, & Spencer, 2015). Consistent with this finding, prior research has indicated that racial/ethnic-minority teachers are more likely than White teachers to believe that the focus of mathematics instruction should be on memorization and procedural skills (Clark et al., 2014).

Another variation in teacher beliefs found across racial/ethnic groups was the greater change in internal locus of control beliefs and non-availing epistemic beliefs of Hispanic teachers compared to their White counterparts. A possible explanation for greater change in beliefs among Hispanics may be a result of cultural differences between Hispanic and White teachers. Den Brok, Levy, Rodriguez, and Wubbels (2002) note that Hispanics tend to come from high power distance societies characterized by an authoritative and strict culture, which promote external locus of control beliefs. Thus, perhaps, Hispanic teachers had more to benefit from a cooperative student-centered, constructivist professional development environment compared to their White counterparts. However, further studies are necessary to understand racial/ethnic differences in teachers' locus of control beliefs and the extent to which these beliefs are affected by professional development experiences.

Change in Teachers' Beliefs in Professional Development

Results suggested that PCK-focused professional development promoted teachers' adaptive educational beliefs about mathematics. This finding echoed what has been repeatedly stated and empirically supported in the literature—that a relationship exists between teachers' PCK and their beliefs (e.g., Loucks-Horsley et al., 2010). While the nature of the relationship between the two constructs has been conceptualized differently in the literature (Ball, 1996; Guskey, 2002), Desimone (2009) has proposed a professional development outcome model where change in teacher knowledge and beliefs occurs before their enactment of instructional practices. Consistent with this theory, other models note that professional development is one of the key stimuli for teacher change, and specifically changes in teachers' beliefs (Ball, 1996).

Therefore, the residual effect of content-focused professional development on teacher beliefs is not surprising. This finding is further elucidated when considering the nature of PCK—that it involves knowledge of content and students, knowledge of content and teaching, and knowledge of curriculum (Hill et al., 2008). Thus, improving PCK would yield improvement in all of these areas, which would also produce more adaptive beliefs related to mathematics knowledge for teaching. In terms of the change in the three different types of beliefs, results showed that changes that occurred in self-efficacy beliefs, internal locus of control beliefs, and non-availing epistemic beliefs were very similar.

We also examined whether the changes in beliefs differed by teaching grade level given that research shows that teachers of lower grades (i.e., elementary) have less content-specific coursework than those of higher grades (i.e., secondary; NRC, 2010; Schmidt et al., 2007). In this study, grades K-6 teachers increased their self-efficacy more than grades 7-12 teachers did. Teachers in K-6 had lower levels of self-efficacy at the onset of professional development. By the end of professional development, they caught up with 7-12 teachers by growing significantly more than 7-12 teachers in self-efficacy beliefs.

Elementary teachers had higher levels of internal-locus of control beliefs at the onset and at the end of professional development. This implied that elementary teachers felt they had more

control over their students' mathematics achievement-related outcomes. This finding is novel, as associations between the teaching grade level and internal locus of control have not been well documented in the literature. The internal locus of control differences between elementary and secondary teachers may be explained by findings indicating that student motivation and engagement in the academic content decreases by grade level (Otis, Grouzet, & Pelletier, 2005). Because it is harder to motivate older students, teachers of higher grades might attribute students' mathematics achievement to other external factors that might have to do with motivation such as whether they attend extra tutoring. In terms of the change in locus of control beliefs, however, elementary and secondary teachers grew at about the same level in internal-locus of control. Therefore, no significant differences in the change in internal locus of control beliefs were detected through participation in professional development.

Lastly, epistemic beliefs of teachers in both groups were at about the same level at the onset of the program. Both groups grew significantly and by about the same amount and ended the program with approximately the same level of non-availing epistemic beliefs. Therefore, the change, although significant for both groups, did not differ across elementary and secondary teachers.

Teachers' Beliefs and MKT

Of the three educational beliefs examined in this study, teachers' epistemic beliefs were the strongest predictor of their MKT. Specifically, higher levels of non-availing epistemic beliefs were associated with poorer performance on an assessment of their knowledge for teaching mathematics. This finding perhaps is not surprising given that a component of Mathematical Knowledge for Teaching involves knowledge not only about content but also about how students think and learn mathematics (Hill et al., 2008). If teachers have non-availing epistemic beliefs about mathematics, they are also more likely to have beliefs that there is only a single way to solve mathematics problems by having students memorize procedures (see Muis, 2004). This view of mathematics knowledge and mathematics instruction would seem to hinder the exploration of understanding students' possible misconceptions that may emerge from their varying approaches in solving mathematics problems. The understanding that is gained from investigating students' preconceptions and conceptions is characteristic of pedagogical content knowledge and specifically knowledge of content and students (KCS; Hill et al., 2008). This positive association between availing epistemic beliefs in mathematics and better performance in this domain in relation to teaching also aligns with research that has found that more availing epistemic beliefs is linked to higher performance in mathematics among student populations (see Muis [2004] for review).

Despite the MKT growth among teachers who participated in the professional development program, racial differences still emerged in teachers' MKT at the end of the professional development intervention. Results indicated that Black teachers had lower scores, on average, on the LMT compared to their White counterparts. Moreover, this relation remained statistically significant after incorporating mathematics background variables and teachers' educational beliefs in the model. There are several reasons why Black teachers may have lower scores on the MKT compared to their White counterparts. First, Black teachers tended to have greater levels of non-availing epistemic beliefs, which we found to be negatively associated with MKT scores as explained in previous paragraphs. Second, there are indications from extant

research that teachers working in higher poverty schools (greater percentage of free and reduced lunch eligible students) are also more likely, on average, to have weaker MKT scores (Hill, 2007; Hill, 2010). As mentioned, Black teachers participating in this study were teaching at schools with a higher percentage of economically disadvantaged students. While there seems to be consistency between previous and current findings in terms of the association between a schools' socioeconomic environment and its quality of mathematics instruction, further investigations are necessary to understand the larger environmental factors that contribute to this relationship. The need to examine the environmental "fit" of teachers with respect to which their teaching beliefs and approaches align with other teachers in their school, and the extent to which environmental fit influences their mathematics knowledge for teaching and instruction, is an area in need of further research (Youngs, Pogodzinski, Grogan, & Perrone, 2015).

Furthermore, while no significant differences were found between Black and White teachers in their years of mathematics teaching experience and the number of mathematics college hours taken in the current study, the educational inequalities that Black teachers potentially experienced in their own K-12 experiences (e.g., Lubienski, 2002) may account for their lower MKT performance. Given that a significant portion of the LMT assesses knowledge of mathematical content, research related to racial differences in mathematics achievement tests may also inform current findings. There are several explanations provided by researchers for the mathematics achievement gap between Black and White students including the lower quality of mathematics instruction that Black students tend to receive as well as the greater frequency of testing (which tends to promote procedural skills over conceptual understanding) of Black students (Lee & Reeves, 2012; Lubienski, 2002). These findings highlight the need for professional development programs to consider not only teachers' post-secondary educational background in the domain they teach, but also their school's socioeconomic environments and teachers' own K-12 mathematics educational experiences when employing interventions aimed to enhance MKT and adaptive educational beliefs.

Limitations

There were several limitations to the current study that should be addressed. First, our sample size was small, especially in the analysis that included LMT as an outcome. However, given the fact that significant effects still emerged provides further support that these significant associations were unlikely due to chance. Second, even though our regression analyses predicting teachers' educational beliefs indicated that racial/ethnic minority teachers were more likely to hold non-availing epistemic beliefs, respective correlation analyses indicate that this association only pertained to Black teachers. This suggests that the significant associations found between other ethnic-minority teachers and non-availing epistemic beliefs may have been due to suppressor effects (Meyers, Gamst, & Guarino, 2006). Finally, while findings suggest that professional development aimed at enhancing teachers' MKT knowledge seems to promote adaptive educational beliefs about mathematics among teachers, no causal inferences can be made based on this research design. Nevertheless, current findings add to our understanding of which discipline-specific antecedents play a stronger role in the development of certain types of educational beliefs among teachers and which teacher beliefs are more strongly tied to MKT.

Recommendations/Implications

The practical implications of current findings for professional programs include the importance of assessing teachers' educational background at the onset of the program given that growth in educational beliefs about mathematics through professional development appears to be a function of prior exposure to mathematics content. This information is important to consider in order for mathematics teacher educators to provide additional support and scaffolding for teachers identified as having weak exposure to mathematics knowledge, which should in turn, enhance their self-efficacy for teaching mathematics. Moreover, while growth was observed for each type of belief, further investigations are needed to determine the specific features of professional development that contribute most to the adaptive development of each type of educational belief about mathematics. Even though the current professional development program seemed to include implicit strategies that enhanced teachers' educational beliefs in a more adaptive direction, perhaps professional development programs should include specific purposeful interventions to further our understanding of what aspects of professional development contribute to the changes in educational beliefs. The predominant role that epistemic beliefs have on teachers' MKT, suggests that professional development programs should enact more purposeful and explicit approaches in developing availing epistemic beliefs about mathematics, especially for racial minority teachers who were more likely to have higher levels of non-availing epistemic beliefs. For example, a previous study found that having teachers read text that refutes traditional teaching approaches while at the same time supports constructivist approaches by providing scientific evidence of its effectiveness changed pre-service teachers' epistemic beliefs about mathematics (Gill et al., 2004). The incorporation of approaches such as these in professional development may lead to greater changes in epistemic beliefs among all teachers.

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