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Linking professional development, teacher outcomes, and student achievement: The case of a learner-centered mathematics program for elementary school teachers☆

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ABSTRACT

Research is needed to examine the link between professional development on both teachers' instruction and student achievement. This study examined the influence of three year-long cohorts of elementary school teachers' participating in a learner-centered mathematics professional development program. Data sources include surveys on teachers' instructional practices and beliefs as well as their students' performance on curriculum-based assessments. Multi-level analyses indicated that teachers' content knowledge and changes in teachers' practices both had statistically significant effects on student achievement. This study advances the knowledge base on the influence of content knowledge and teachers' beliefs on student achievement.

1. Background

1.1. Addressing student performance in mathematics

In response to reports about students from the United States underperforming on international and national assessments (National Center for Educational Statistics, 2013; Organisation for Economic Co-operation and Development [OECD], 2012), mathematics education leaders have called for reform and changes in the way that mathematics is taught in United States schools (National Council for Teachers of Mathematics, 2014; United States Department of Education, 2008). While United States students have demonstrated some gains on the National Assessment for Educational Progress (NAEP) (NCES, 2014), reports from the OECD Programme for International Student Assessment (PISA) state that the United States is below average in mathematics when compared to other developed countries. In fact, the highest scores from Shanghai-China were approximately two grade levels higher than Massachusetts, one of the highest performing states from the United States.

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1.2. Teachers' instruction in mathematics

While considering approaches to improve the teaching and learning of mathematics in the United States, mathematics leaders have made empirically-based recommendations for teachers' mathematics instruction. These leaders have suggested that teachers' should: pose more cognitively-demanding mathematical tasks (Boston & Smith, 2009; NCTM, 2014; Stein, Grover, & Henningsen, 1996), assess their students' understanding and use that information to implement developmentally-appropriate tasks (Carpenter, Fennema, & Franke, 1996; Fennema et al., 1996; Martin & Polly, 2015), and enact a comprehensive curriculum of cohesive activities that support students' mathematical understanding (Stein, Remillard, & Smith, 2007). These pedagogies, and others, are often referred to as standards-based pedagogies, due to their alignment with the *Principles and Standards* from the National Council of Teachers of Mathematics (NCTM, 2000, 2014).

While these recommendations are research-based, studies indicate that teachers struggle trying to implement these pedagogies in their classroom (Boston & Smith, 2009; Carpenter et al., 1996; Polly, 2014; Stein et al., 1996). These struggles include decreasing the cognitive-difficulty or rigor of mathematical tasks by providing students with too much help (Polly & Hannafin, 2011; Stein et al., 1996) and posing tasks that do not always align to students' ability level (Carpenter et al., 1996), or modifying activities in the curriculum due to pressure from school administrators or the need to prepare for large-scale assessments (Boston & Smith, 2009; McGee, Wang, & Polly, 2013). In order for teachers to effectively enact these research-based recommendations, teachers need effective professional learning experiences to support their work (Wang et al., 2013; NCTM, 2014).

1.3. Mathematical knowledge for teaching

Empirical studies continue to confirm how teacher quality is significantly associated with student learning outcomes (Heck, Banilower, Weiss, & Rosenberg, 2008; Nye, Konstantopoulos, & Hedges, 2004). Researchers have strived and continue to work to construct sound frameworks of teacher knowledge to inform the field (Ball, Thames & Phelps, 2008; Schuman, 1986; Mishra & Koehler, 2006). The construct of mathematical knowledge for teaching (MKT) describes teacher knowledge as a variety of different aspects of knowledge about mathematics content, students, pedagogy, and instructional resources (Hill, Rowan, & Ball, 2005). The developers of this construct have created a series of assessments that can be administered to better understand teachers' mathematical knowledge for teaching (Hill et al., 2005). These assessments provide educational leaders and teachers with opportunities to better understand teachers' knowledge of mathematics as it relates to pedagogy.

Hill et al. (2005) found a statistically significant relationship between teachers' mathematical knowledge for teaching and student achievement in both Grades 1 and 3 after controlling for several key student-level and teacher-level covariates. In subsequent studies, researchers have studied teachers during a year-long professional development project and found a statistically significant relationship between kindergarten teachers' mathematical knowledge for teaching and their students' achievement (Polly et al., in press). While teachers' mathematical knowledge for teaching has a relationship with student learning, more work is needed to explicate the extent of the influence of a teachers' knowledge and student achievement.

1.4. Teachers' beliefs about mathematics

Research studies have empirically linked teachers' beliefs related to mathematics teaching to teachers' enacted instructional practices (Fennema et al., 1996), their use of curricula (Remillard, 2005; Stein & Kim, 2009), and their willingness to enact student-centered pedagogies (Heck et al., 2008; Polly et al., 2013; Remillard & Bryans, 2004). Researchers are also uncovering the link between teachers' beliefs, their instruction, and student learning outcomes (Polly et al., 2013; Fennema et al., 1996).

In the seminal Cognitively Guided Instruction (CGI) research project, researchers found that students who were in CGI classrooms for multiple years outperformed students who were in other classrooms on measures of problem solving, and scored no differently on measures of computational skills (Carpenter et al., 1996; Fennema et al., 1996). Further research about the CGI teachers indicated that they had gone through a change in their beliefs about mathematics teaching as well as changes in how they taught mathematics. However, there was no set pattern for the teachers in the CGI professional development about whether their beliefs changed first or their practices; in some cases teachers used their classroom as a laboratory to test out these practices without an initial change in beliefs, while other teachers reported shifts in beliefs during the workshops before then changing their mathematical practices (Fennema et al., 1996).

Both of the changes in teachers' in beliefs and practices were empirically linked to gains in students' achievement.

Data analysis from 35 teachers and 494 students who participated in the first two year-long cohorts of this three cohort project indicated empirical links between teachers' beliefs and their instructional practices, but no statistically significant relationship between beliefs and students' achievement (Polly, Neale, & Pugalee, 2014; Wang et al., 2013). In this study, that data as well as data from the third year of the project was analyzed in order to examine the influence of the professional development on teachers' beliefs, their instruction, their content knowledge and their students' achievement. Based on the refinement of the professional development program (Polly & LeHew, 2012), we seek to examine if there could be a significant relationship between student achievement and the teacher variables that will be examined, including teachers' beliefs, teachers' content knowledge, and teachers' practices.