

## The Development of Mathematics Beliefs of Elementary School Teachers

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**Abstract:** This study investigated the mathematics teaching efficacy and pedagogical beliefs of 103 elementary preservice teachers and how these beliefs at the end of a teacher preparation program compared with those of 66 inservice teachers. The beliefs of the preservice teachers significantly changed during the distinctive program that included developmental, time-intensive field placements and a two-semester mathematics methods sequence. Differences and similarities between the preservice and inservice teachers' beliefs were observed; both groups had similar levels of teaching efficacy, but the preservice teachers held beliefs toward mathematics teaching and learning that were more cognitively oriented.

Beliefs have been defined as the lenses through which an individual looks when interpreting the world and as such affects the way one interacts with the world (Philipp, 2007). When considering this definition in educational contexts, teachers hold interpretive lenses through which they filter experiences in their classrooms that inform their behaviors in this environment. Research has established that teachers' beliefs about mathematics teaching and learning are linked with their instructional strategies and, consequently, student learning in the classroom (Philipp, 2007; Thompson, 1992; Wilson & Cooney, 2002).

Disconcertedly, many preservice teachers (i.e., college students majoring in education) and inservice teachers (i.e., practicing teachers) in the United States hold belief systems about mathematics teaching and learning that are inconsistent with the reform perspective of the National Council of Teachers of Mathematics (NCTM). Most teachers have an extensive set of core beliefs about mathematics as a fixed set of facts and procedures with the knowledge authority residing in textbooks; further, teachers serve as the intermediary between the textbooks and students (Smith, 1996). Traditional teaching of mathematics is about telling, or providing clear, step-by-step explanations of procedures while students learn by listening and practicing these procedures. The research literature makes a compelling argument for the deficiencies of this traditional approach (Hiebert, 2003), which is in contrast to the reform perspective of NCTM (1989, 1991, 2000) that advocates a constructivist view of teaching and learning emphasizing students' conceptual understandings and discourse in the mathematics classroom. Studies have revealed the benefits of such reform instructional programs and demonstrated that students can acquire both mathematical concepts and skills at higher levels than in comparative traditional programs (Hiebert, 2003).

Within this context of reform in mathematics education, a challenge for teacher preparation programs is the limited amount of time, usually two years or less, to impact the beliefs of preservice teachers. Programs must provide experiences that nudge preservice teachers' mathematics pedagogical beliefs toward alignment with the reform perspective and increase their efficacy for teaching mathematics. Changing these beliefs is a difficult process. Efficacy beliefs are often informed by past experiences (Bandura, 1977); hence, most preservice teachers' sense of teaching efficacy is founded on traditional notions of mathematics education rather than the reform perspective. Further, changing pedagogical beliefs is an arduous process

requiring thoughtful reflection and the realization of benefits for students (Philipp, 2007). Previous research on preservice teachers' mathematics beliefs has mostly examined these constructs in the context of a single mathematics methods course. This study seeks to go a step further by examining changes in beliefs across a teacher preparation program and how these beliefs at the end of the program compare to those of inservice teachers.

## Related Research

### *Teaching Efficacy Beliefs*

Research has established a robust relationship between teaching efficacy and classroom instructional strategies (Weirtheim & Leyser, 2002), willingness to embrace educational reform (Hami, Czerniak, & Lumpe, 1996), and important student outcomes such as achievement and motivation (Tschannen-Moran & Hoy, 2001). Using Bandura's (1977) theoretical framework of self-efficacy, teacher efficacy is considered by many researchers to be a two-dimensional construct (Enochs, Smith, & Huinker, 2000). The first factor, personal teaching efficacy, represents a teacher's belief in his or her skills and abilities to be an effective teacher. The second factor, teaching outcome expectancy, is a teacher's belief that effective teaching can bring about student learning regardless of external factors such as home environment, family background, and parental influences.

Bandura's theory of self-efficacy suggests that efficacy beliefs may be most malleable early in learning; therefore, Hoy (2004) argues that the first few years of teacher development are critical to the long-term development of teaching efficacy. Further, once teaching efficacy beliefs are established, they are highly resistant to change. Studies suggest that coursework and the student teaching experience have differential impacts on the personal teaching efficacy beliefs and teaching outcome expectancy beliefs of preservice teachers. Personal teaching efficacy increases during coursework and continues to increase during the student teaching experience (Hoy & Woolfolk, 1990; Plourde, 2002). However, teaching outcome expectancy beliefs increase during college coursework but decline during student teaching. This decline has been attributed to the often unrealistic optimism of preservice teachers prior to student teaching toward teachers' abilities to overcome negative influences (Hoy & Woolfolk, 1990).

Although there have been numerous studies on teaching efficacy, there has been less research specifically on the mathematics teaching efficacy of elementary preservice teachers. Most of the previous studies examined the effects of a single mathematics methods course and have indicated significant increases in mathematics teaching efficacy on completion of the course (Huinker & Madison, 1997; Utley, Moseley, & Bryant, 2005).

### *Pedagogical Beliefs*

The pedagogical beliefs of preservice teachers should be targets of change during the teacher preparation process as studies have strongly linked these beliefs with teacher thinking and behaviors, including instructional decision-making and use of curriculum materials, as well as student learning in mathematics (Philipp, 2007; Thompson, 1992; Wilson & Cooney, 2002). Studies of changes in mathematics pedagogical beliefs of preservice teachers have largely focused on aligning beliefs more closely with a reform perspective on teaching and learning. Typically, studies have looked at changes over one mathematics methods course with some methods courses not achieving the desired effect (Ball, 1989; Simon & Mazza, 1993), while

more current studies of methods courses resulted in the desired changes (Hart, 2002; Lubinski & Otto, 2004; Spielman & Lloyd, 2004; Wilkins & Brand, 2004).

A number of studies focusing on pedagogical beliefs have examined teachers' beliefs related to students' mathematical thinking (Philipp, 2007). Preservice teachers typically care intensely about their students, but not necessarily about mathematics (Darling-Hammond & Sclan, 1996). So, mathematics methods courses that help preservice teachers learn about student thinking are important to teacher development (Philipp). Studies examining the impact of Cognitively Guided Instruction (CGI) as a model for teaching and learning mathematics have specifically investigated changes in teachers' beliefs toward students' mathematical thinking. CGI, which is situated in a constructivist paradigm, focuses on teachers using knowledge of children's mathematical thinking to make instructional decisions (Carpenter & Fennema, 1991). This model has four important tenets: (a) children can construct their own mathematics knowledge, (b) mathematics instruction should be organized to facilitate children's construction of knowledge, (c) children's development of mathematical ideas should provide the basis for sequencing topics for instruction, and (d) mathematical skills should be taught in relation to understanding and problem solving (Peterson, Fennema, Carpenter, & Loef, 1989). Vacc and Bright (1999) explored the influence of introducing CGI to preservice teachers. They administered a pedagogical belief survey to 34 preservice teachers 4 times over a two-year period during a teacher preparation program. They found little change during the first year but substantial change during the second year; this finding reinforces the need to study beliefs over time.

### Research Questions

1. How do elementary preservice teachers' mathematics teaching efficacy and pedagogical beliefs change during a teacher preparation program?
2. Is there a difference between elementary preservice teachers' mathematics teaching efficacy and pedagogical beliefs at the end of a teacher preparation and those of inservice teachers?

### Methodology

#### *Participants and Setting*

The participants in this study were 103 elementary preservice teachers and 66 elementary inservice teachers. The preservice teachers were enrolled in a two-year undergraduate teacher preparation program at a large urban university in the southeastern United States. The preservice teachers included five cohorts of students with each cohort completing all education courses concurrently. The program consisted of four semesters of coursework that included two mathematics methods courses taught in consecutive semesters. Each of the first three semesters included two-day-a-week field placements followed by a semester of student teaching. Student teaching placements were typically in urban schools with the majority of these schools having Title I status. The field placements and coursework followed a developmental model with preservice teachers starting their placements in pre-kindergarten and finishing in fifth grade prior to student teaching. Other mathematics requirements in the program included three mathematics content courses for teachers taught through the mathematics department (number and operations, geometry, and statistics) in addition to the university requisite mathematics coursework.

The mathematics methods courses were taught by faculty in the elementary education department who shared a common philosophical orientation toward the teaching and learning of mathematics. Thus across the courses the focus was consistent with the constructivist paradigm espoused by the *Principles and Standards for School Mathematics* (NCTM, 2000) in that all students should learn important mathematical concepts and processes with understanding. The preservice teachers were exposed to the features of a *Standards-Based Learning Environment* with a focus on the processes of problem solving, representations, communication, connections, and reasoning and proof. Important goals of the courses included developing: (a) beliefs consistent with the perspective of the *Principles and Standards*, (b) understanding of children's thinking about important mathematics concepts, (c) abilities to create problem-solving learning environments for children to facilitate discourse and understanding, and (d) abilities and confidence as a lifelong learner and doer of mathematics. The first course focused on content and pedagogy for pre-kindergarten through second grade students with field placements in those grades. The second course emphasized third through fifth grades with accompanying field placements in those grades.

The inservice teachers in this study were at a large, suburban elementary school located relatively close to the university. The elementary school and university are considered to be in a Professional Development School (PDS) relationship. As such, the elementary school provides a number of placements for preservice teachers in the teacher preparation program. Of the 66 inservice teachers in this study, 12 taught kindergarten, 11 taught first grade, 9 taught second grade, 10 taught third grade, 9 taught fourth grade, 7 taught fifth grade, 5 taught special education, and 3 were mathematics specialists. Additional demographic data were not collected due to teachers' concerns around anonymity. However, published data on this school indicated teachers' years of teaching experience ranged from 5 years or less (43%), 6 to 10 years (27%), and more than 10 years (30%). Slightly more than half (52%) of the teachers had advanced degrees. Teacher turnover is problematic at the school with approximately one-third of teachers leaving each year during the three years prior to this study.

The elementary school was a Title I school with 88% of the students eligible for free or reduced lunches at the time of this study. Student population was comprised of 59% Hispanic, 23% African American, 11% Asian, and 4% Caucasian. Seventy-two percent of the students were non-native English speakers, and 47% of the student population was participating in the English as a Second Language (ESL) program. The school has a high rate of student mobility. In 2002, this school was removed from the state's failing schools list and has achieved adequate yearly progress (AYP) goals every year since this removal.

The researcher in this study served in the role of PDS university liaison at this elementary school and as such frequently provided professional development focused on the reform perspective in mathematics. The researcher was familiar with the mathematics curriculum used by the teachers. This curriculum is considered more of a traditional approach to mathematics education rather than one from a reform perspective.

### *Instrumentation*

Two instruments, the Mathematics Teaching Efficacy Beliefs Instrument (MTEBI) and the Mathematics Beliefs Instrument (MBI), were administered to the participants. The preservice teachers completed the instruments prior to their first mathematics methods course and at the end of student teaching. The inservice teachers completed the instruments toward the beginning of

the academic school year. Table 1 shows the context of the study for the preservice teachers including the points of data collection for the two instruments, the sequence and length of placements for the developmental model, and when the two mathematics methods courses were completed.

Table 1

*Sequence of Teacher Preparation Program and Data Collection*

	Semester 1	Semester 2	Semester 3	Semester 4
Mathematics methods courses	None	Focus on PreK-2 <sup>nd</sup> grades math	Focus on 3rd-5 <sup>th</sup> grades math	None
Field Placements	PreK – 5 weeks K – 9 weeks	1st – 7 weeks 2 <sup>nd</sup> or 3 <sup>rd</sup> – 7 weeks	4 <sup>th</sup> – 7 weeks 5 <sup>th</sup> – 7 weeks	Student teaching
Administration of MTEBI & MBI	None	Week one INITIAL	None	Week fourteen FINAL

The MTEBI consists of 21 items, 13 on the Personal Mathematics Teaching Efficacy (PMTE) subscale and 8 on the Mathematics Teaching Outcome Expectancy (MTOE) subscale (Enochs, Smith, & Huinker, 2000). The two subscales are consistent with the two-dimensional aspect of teaching efficacy. The PMTE subscale addresses the preservice teachers' beliefs in their individual capabilities to be effective mathematics teachers. The MTOE subscale addresses the preservice teachers' beliefs that effective teaching of mathematics can bring about student learning regardless of external factors. The instrument uses a Likert scale with five response categories (strongly agree, agree, uncertain, disagree, and strongly disagree) with higher scores indicating greater teaching efficacy. These subscales have high reliability (Chronbach's alpha = .88 for PMTE and .81 for MTOE) and represent independent constructs based on confirmatory factor analysis.

The MBI is a 48-item Likert scale instrument designed to assess preservice teachers' beliefs about the teaching and learning of mathematics and the degree to which these beliefs are cognitively aligned (i.e., aligned with a constructivist perspective) (Peterson et al., 1989, as modified by the Cognitively Guided Instruction Project). The three subscales include: (a) relationship between skills and understanding (CURRICULUM), (b) role of the learner (LEARNER), and (c) role of the teacher (TEACHER). The 16-item CURRICULUM subscale examines the degree to which teachers believe that mathematics skills should be taught in relation to understanding and problem solving. The LEARNER subscale contains 15 items that assess the degree to which teachers believe that children can construct their own mathematical knowledge. The 17 items on the TEACHER subscale address the extent to which teachers believe that mathematics instruction should be organized to facilitate children's construction of knowledge. The instrument uses a Likert scale with five response categories (strongly agree, agree, uncertain, disagree, and strongly disagree) with higher scores indicating beliefs that are more cognitively aligned. These subscales have high reliability (Chronbach's alpha = .80 for

CURRICULUM, .89 for LEARNER, and .90 for TEACHER) and represent independent constructs based on confirmatory factor analysis.

## Results

Mean scores and standard deviations from the administrations of the MTEBI subscales and MBI subscales are provided in Table 2. Table 3 indicates the statistical significance of the differences between the initial and final mean scores of the preservice teachers using Wilks' Lambda and its associated F-statistic.

Table 2

*Means and Standard Deviations for Mathematics Teaching Efficacy and Pedagogical Beliefs Scores\**

Subscales	Preservice Teachers				Inservice Teachers	
	Means		Standard deviations		Means	Standard deviations
	Initial	Final	Initial	Final		
PMTE	3.54	4.18	.56	.65	4.06	.65
MTOE	3.44	3.64	.40	.51	3.60	.52
CURRICULUM	3.04	3.34	.32	.49	3.11	.49
LEARNER	3.08	3.55	.43	.60	3.15	.40
TEACHER	3.31	3.77	.39	.58	3.46	.37

\* Represented on a five point Likert scale

The findings related to the research question of changes in preservice teachers' beliefs during the teacher preparation program revealed significant increases in PMTE and MTOE subscale mean scores, as indicated in Table 3. During the teacher preparation program the preservice teachers became more confident in their skills and abilities to teach mathematics effectively; further, their beliefs that effective teaching of mathematics can bring about student learning increased significantly. When comparing mean changes (see Table 2), their personal teaching efficacy beliefs showed greater shifts than beliefs related to outcome expectancy. Data from the CURRICULUM, LEARNER, and TEACHER subscales also revealed significant shifts in mean scores (see Table 3). The preservice teachers' beliefs about teaching and learning mathematics became more cognitively aligned during the teacher preparation program.

Table 3

*F-Values and P-Values for Preservice Teachers' Mathematics Teaching Efficacy and Pedagogical Beliefs Scores\**

Subscales	F-Value	P-Value
PMTE	26.22	.000
MTOE	6.88	.000
CURRICULUM	19.35	.000
LEARNER	37.76	.000
TEACHER	33.37	.000

\*df = 3, 100

In order to address the research question of comparing the beliefs of the preservice teachers' at the end of the program with the beliefs of inservice teachers, independent samples *t*-tests were applied to the data. The analysis revealed no significant differences in the mean scores of the PMTE subscale  $t(167) = 1.18, p = .241$  and the MOTE subscale  $t(167) = .432, p = .666$ . At the end of the teacher preparation program, the preservice teachers' teaching efficacy beliefs were similar to those of the inservice teachers. However, data analysis indicated significant differences in the CURRICULUM  $t(167) = 2.70, p = .008$ , LEARNER  $t(167) = 4.94, p = .000$ , and TEACHER  $t(167) = 3.78, p = .000$  subscales mean scores. When comparing the pedagogical beliefs of the preservice teachers at the end of the program with those of the inservice teachers, the preservice teachers' had more cognitively oriented beliefs toward the teaching and learning of mathematics.

### Discussion and Conclusions

The preservice teachers in this study were enrolled in a distinctive teacher preparation program that provided a developmental model for time-intensive field placements; also included was a two-semester sequence of mathematics methods courses that emphasized a constructivist approach to teaching and learning in congruence with the NCTM reform perspective. These particular experiences of the preservice teachers facilitated significant shifts in their mathematics teaching efficacy and pedagogical beliefs. Even with the enculturation experience of student teaching, these shifts were evident at the end of the program.

Consistent with previous research focusing solely on the context of mathematics methods courses (Huinker & Madison, 1997; Utley et al., 2005), the preservice teachers' beliefs in their skills and abilities to teach mathematics effectively and influence student learning significantly increased during the teacher preparation program. The program design provided two influential sources for building the efficacy beliefs of the preservice teachers: performance accomplishments and vicarious experiences (Bandura, 1977). Bandura proposed that the most effectual means of building efficacy beliefs is through mastery experiences; successes while

engaging in an activity build a strong belief in one's personal efficacy while failures undermine it. The structure of the program in providing substantial field experiences, including two days per week during the second and third semesters and then daily during student teaching, afforded numerous opportunities for teaching mathematics. Further, across all sections of the mathematics methods courses, the instructors required the preservice teachers to create numerous mathematics lessons and implement these lessons in elementary classrooms. The programmatic aspect of concurrent field placements during the methods courses allowed the preservice teachers to immediately implement teaching strategies learned in their methods courses thus providing for a strong connection between theory presented in coursework and practices in elementary classrooms. These program features and expectations allowed for ample opportunities for mastery experiences in teaching mathematics, thus suggesting one source for the building of the preservice teachers' efficacy beliefs in teaching mathematics. Bandura (1977) argued that the second most influential source of building efficacy beliefs is through the vicarious experiences of observing social models. The teacher preparation program provided two semesters of mathematics methods rather than the typical one-semester requirement in most teacher preparation programs. Thus, the preservice teachers' protracted observations of effective mathematics instruction as modeled by university faculty, as well as some of their cooperating teachers in the field placements, suggests an additional source for increased efficacy beliefs.

Also consistent with previous studies on mathematics methods courses (Hart, 2002; Spielman & Lloyd, 2004; Wilkins & Brand, 2004), the pedagogical beliefs of the preservice teachers significantly shifted toward cognitive alignment and hence a reform perspective during the teacher preparation program. The preservice teachers developed stronger beliefs that mathematics skills should be taught in relation to understanding and problem solving rather than in isolation. Further, they developed more substantial beliefs that the role of the teacher during mathematics instruction is to facilitate children's construction of knowledge rather than simply present materials; moreover, children are able to construct their own mathematical knowledge instead of being merely receivers of knowledge. The mathematics methods courses immersed the preservice teachers in a reform perspective, and they were given opportunities to experience success in implementing reform practices in their field placements. They were supported by university mathematics faculty and frequently saw the benefits of a constructivist approach to teaching and learning, which the research literature indicates is an important aspect of changing pedagogical beliefs (Philipp, 2007). Given the enculturation experience of student teaching, which is often in schools that take a more traditional approach to mathematics education, it is promising that the preservice teachers held these cognitively oriented beliefs at the end of the program. The two-semester duration of the mathematics methods courses seems to have allowed time for these beliefs to become somewhat established.

In comparing the beliefs of the preservice teachers at the end of the program with those of inservice teachers, the data revealed similarities and differences. The teaching efficacy beliefs of the preservice teachers were comparable to those of the inservice teachers; both groups held similar beliefs about their skills and abilities to teach mathematics effectively (PMTE) and influence student learning (MTOE). This finding is of interest because preservice teachers often have unrealistic expectations toward what teachers can accomplish, resulting in inflated teaching outcome expectancy beliefs (Hoy & Woolfolk, 1990). The specific component of this teacher preparation program of time-intensive, extensive field placements most likely contributed to the preservice teachers in this study having more realistic expectations about their abilities to influence student learning at the end of the program.

However, the pedagogical beliefs of the preservice and inservice teachers were significantly different. It has been noted that beliefs should be considered and interpreted as contextualized and situated (Hoyles, 1992). The pressures on the inservice teachers to meet Adequate Yearly Progress (AYP) goals with an emphasis on high stakes testing undoubtedly influenced their beliefs about teaching and learning mathematics. These constraints compel teachers to teach in such a way that students meet performance standards, which often preclude an emphasis on conceptual understandings in mathematics (Philipp, 2007). More specific to this study, the inservice teachers were at an elementary school that had been identified as low-performing and recently removed from the state's failing schools list. The competing values of improving students' test scores and creating learning environments that develop deep understandings of mathematics place teachers in a conundrum where they must make choices among conflicting priorities. Obviously, the preservice teachers in this study had limited notions of these competing forces in the mathematics classroom. The research literature suggests that changing the mathematics pedagogical beliefs of inservice teachers toward constructivist orientation necessitates professional development in mathematics that has two distinct components (Phillip, 2007). First, teachers must be challenged to reflect on their existing beliefs systems for changes to occur. Second, teachers must develop an understanding of the benefits of a constructivist perspective on teaching and learning on student outcomes for changes to take place, thus professional development that focuses on the mathematical thinking of students is essential.

Although preservice teachers enter teacher preparation programs with well-entrenched beliefs about mathematics teaching and learning (Pajares, 1992) generated during their formative years as students in classrooms (Lortie, 1975), the results of this study indicate that teacher preparation programs can impact these beliefs. It is clear that the features of this teacher preparation program positively impacted mathematics beliefs. What will happen to the beliefs of the preservice teachers after the induction period into the education profession is not known, particularly if their pedagogical beliefs will become less cognitively-aligned and similar to the inservice teachers in this study. Additionally, how these beliefs will play out in teaching practices in the classroom is unknown. Both of these areas warrant further investigation for another study. However, this longitudinal study informs us of the impact of our developmental, field-intensive teacher preparation program, which includes two mathematics methods courses, on preservice teachers to better prepare them as they enter the teaching profession.

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