A MULTIPLE-CASE STUDY OF ELEMENTARY PROSPECTIVE TEACHERS' EXPERIENCES IN DISTINCT MATHEMATICS CONTENT COURSES

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This multiple-case study explored the experiences of two groups of elementary prospective teachers (n=12) completing distinct mathematics content courses. Individual interviews revealed perspectives on knowing, learning, and teaching mathematics as experienced by the two groups; the quantitative findings indicated differences in mathematical beliefs. One group characterized mathematics as a record of knowledge, difficult to understand and lacking in relevance; learning occurred through rote memorization and via external expertise, with teaching typified as explaining. The other group portrayed mathematics as process-focused, internally constructed, and relevant; learning took place through a focus on children's thinking, with teaching characterized as guiding and questioning.

The context for this study was an elementary teacher preparation program that was evolving in response to university system mandates requiring more courses in mathematics content for elementary teachers. Specifically, programs had to include a particular 3-hour course in elementary mathematics during the sophomore year in addition to 9 hours of upper-division mathematics courses. Throughout this period, mathematics department faculty members developed and taught the required courses for elementary teachers in Number and Operations, Algebra, Geometry, and Statistics.

Many prospective teachers failed or withdrew from these courses and consequently had to defer student teaching. Over one 4-semester period (Fall 2004-Spring 2006), 24.8% of prospective teachers did not complete or pass one or more of these mathematics courses. In response to this troubling trend, an experimental group of prospective teachers enrolled as a cohort in a one-time sequence of four content courses having specific foci on the perspectives of the National Council of Teachers of Mathematics (NCTM, 2000) and the development of the *specialized content knowledge* (SCK) needed for teaching elementary mathematics. This experimental sequence is referred to here as the "alternative courses" and was taught by an instructor in the elementary education department (grades PreK-5). The other group of prospective teachers in this study participated in what is referred to here as the "traditional courses" taught by instructors in the mathematics department.

This study explored these two groups of teacher candidates' (n=12) perspectives on knowing, learning, and teaching mathematics in the context of these experiences, as well as their mathematical beliefs and affect. More specifically, this study used a multiple-case design that

Wiest, L. R., & Lamberg, T. (Eds.). (2011). Proceedings of the 33rd Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education. Reno, NV: University of Nevada, Reno.

applied mixed methods to explore the following research questions: (1) What are the perspectives on knowing, teaching, and learning mathematics of two groups of elementary prospective teachers' in the context of distinct mathematics courses? and (2) What are the mathematical beliefs and affect of these prospective teachers?

Theoretical Perspectives and Related Research

Perspectives on Teacher Knowledge in Mathematics

A pressing concern for elementary teacher preparation programs is the development of adequate and appropriate mathematical content knowledge. The precise nature of this knowledge has prompted significant debate in the mathematics education community (Ball, Hill, & Bass, 2005; Hill, 2010; Rowland, Huckstep, & Thwaites, 2005). In recent years, researchers (Ball, Hill, & Bass, 2005; Ball, Thames, & Phelps, 2008; Hill 2010) have proposed a *specialized content knowledge* (SCK) described as "the mathematical knowledge 'entailed by teaching' - in other words, mathematical knowledge needed to perform the recurrent tasks of teaching mathematics to students" (Ball et al., 2008, p. 399). Examples of SCK include teachers' abilities to: (a) analyze and interpret students' mathematical thinking and ideas, (b) use multiple representations of mathematical concepts, and (c) define terms in mathematically correct and accessible ways.

Teacher Beliefs and Affect

Prospective teachers come to the teaching profession with deep-rooted mathematical beliefs and affect formed during their seminal years as students in K-12 classrooms (Lortie, 1975); they resist changing these beliefs and affect as they move through teacher preparation programs (Phillip, 2007). Three teacher belief constructs are relevant to this study including: efficacy beliefs, pedagogical beliefs, and beliefs about the nature of mathematics. The first belief construct, teacher efficacy, has been defined as teachers' beliefs in their skills and abilities to teach mathematics effectively and influence student learning (Hoy, 2004). The second belief construct, pedagogical beliefs, includes teachers' beliefs related to how they should teach and how students should learn; these beliefs can be viewed as grounded in theories of learning. Lastly, beliefs about the nature of mathematics include what mathematics is as a subject or what it means to know and do mathematics, ranging from mathematics as unrelated facts, rules, and skills to mathematics as problem solving, fluid and expanding in nature (Handal, 2003; Wilkins, 2008).

Elementary Prospective Teachers' Experiences in Mathematics Content Courses

Studies of elementary prospective teachers' experiences in mathematics content courses have focused on efforts to align the curriculum and instructors' practices with current reform recommendations (Lubinski & Otto, 2004; Philipp et al., 2007; Royster, Harris, & Schoeps, 1999). Royster et al. found that elementary education majors showed the greatest positive changes in mathematical dispositions when compared to other majors upon completion of a mathematics course that had been revised for congruence with reform recommendations. In another study, Phillip et al. concluded that prospective teachers in a mathematics course studying children's mathematical thinking developed more sophisticated beliefs about mathematics and improved their mathematical content knowledge than prospective teachers who did not have children's thinking as a focus.

Studies have also examined college students' perceptions of effective mathematics teaching and learning (Harkness, D'Ambrosio, & Morrone, 2006; Powell-Mikle, 2003; Schulze & Tomal,

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2006). For example, Powell-Mikle reported certain classroom characteristics that support student learning in mathematics: adequate instructor availability, clear instructor explanations, prevalent classroom discourse, and a caring classroom environment. Schulze and Tomal's sizeable study of 2,042 college students examined factors contributing to a "chilly" mathematics classroom climate, which include: difficulty level of course content, teaching style/personality of the professor, and personality styles of classmates.

Methodology

The design of this study included a descriptive, holistic multiple-case approach (Yin, 2003). A case study methodology was applied as it was "impossible to separate the phenomenon's variables from the context," (Merriam, 1998, p. 29) and two bounded units were investigated. The two cases, which were the units of study and analyses, were the distinct mathematics course experiences, and the purpose of the study was to provide a "thick description" (Merriam, 1998, p. 29) of each. Further, this rich description provided opportunities to compare and contrast across the two mathematics course experiences in the interpretation of the findings.

Within this multiple-case design, mixed methods were applied. More specifically, a "concurrent triangulation" (Creswell, Clark, Gutmann, & Hanson, 2003, p. 224) approach to mixed methods was used, with data collection occurring via individual interviews and surveys. In this present study, the concurrent triangulation approach implies: (a) quantitative and qualitative data were collected concurrently, (b) qualitative data were given priority, and (c) integration occurred in the interpretation phase.

Participants and Setting

The participants were 12 randomly selected prospective teachers enrolled in an elementary teacher preparation program at a large, urban university in the southeastern U.S. The gender of the participants included 11 females and 1 male. At the time of this study, the participants were in the student teaching semester of the program. The program was two years in duration and included three semesters of courses with concurrent two-day-per-week field placements, followed by a full semester of student teaching.

The participants had completed one mathematics methods course and the four required mathematics content courses for elementary teachers. The mathematics methods course was taken during the second semester of the program and taught by instructors in the elementary education department. The content courses were Number and Operations (lower level), Geometry, Algebra, and Statistics (all upper level). As an admittance requirement, all 12 of the prospective teachers completed the Number and Operations course prior to entering the teacher preparation program. The other content courses were completed at different times during the program but were finished prior to the student teaching semester.

Six of the prospective teachers experienced the "traditional courses" (see introduction) taught by various instructors in the mathematics department, and six prospective teachers experienced the "alternative courses" taught by an instructor from the elementary education department. The nature of the course experiences is best viewed from the responses of the participants who experienced the courses firsthand; however, a syllabi analysis revealed that in general the two sets of courses focused on the same mathematics content with considerable differences in the nature of this knowledge as well as the ways in which this content was taught and learned. One major difference in these approaches was that the alternative courses included a significant amount of time studying children's development of mathematical thinking, problem solving, and understanding, whereas

the traditional courses focused primarily on memorization of formal definitions and proficiency with standard algorithms.

Instruments and Data Collection

This mixed methods study included qualitative data collected via individual interviews and quantitative data collected via two belief surveys. Data collection occurred during the student teaching semester of the teacher preparation program.

The interview protocol included six multi-part questions such as: (a) What are your overall impressions of the math courses? What was easy and hard? What did you like and dislike? (b) After taking the math courses, do you feel confident that your content knowledge is sufficient to understand PreK-5 math? Why or why not? and (c) After taking the math courses, do you feel prepared to analyze children's math strategies in grades PreK-5? Why or why not? The semi-structured interviews were conducted at the convenience of the prospective teachers at the researchers' offices or the student teaching schools.

Two belief surveys were completed by the prospective teachers on campus: the Mathematics Beliefs Instrument (MBI) and the Mathematics Teaching Efficacy Beliefs Instrument (MTEBI). The MBI is a 48-item Likert scale instrument designed to assess teachers' beliefs about the teaching and learning of mathematics and the degree to which these beliefs are cognitively aligned (Peterson, Fennema, Carpenter, & Loef, 1989, as modified by the Cognitively Guided Instruction Project). The three subscales include: (b) role of the learner (Learner), (b) relationship between skills and understanding (Curriculum), and (c) role of the teacher (Teacher). The Learner subscale contains 15 items that assess the degree to which teachers believe that children can construct their own mathematical knowledge. 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 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 =.89 for Learner, .80 for Curriculum, and .90 for Teacher) and represent independent constructs based on confirmatory factor analysis.

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 teacher efficacy. The PMTE subscale addresses the prospective teachers' beliefs in their individual capabilities to be effective mathematics teachers. The MTOE subscale addresses the prospective 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, with higher scores indicating greater teaching efficacy. Possible scores on the PMTE subscale range from 13 to 65; MTOE subscale scores range from 8 to 40. These subscales have high reliability (Chronbach's alpha = .88 for PMTE and .81 for MTOE) and represent independent constructs based on confirmatory analysis.

Data Analysis

This multiple-case design included analysis of the data within each case. Audiotapes of the interviews were transcribed and analysis of the data began by applying the *a priori* codes of

knowing, learning, and teaching mathematics as experienced by the two groups of prospective teachers in the mathematics courses. Through this process an additional code emerged: beliefs and affect. Researchers used constant comparative methods (Lincoln & Guba, 1985) to generate more refined categories within these codes. Specifically, researchers individually analyzed the qualitative data through open coding, which generated numerous categories and subcategories that represented observed phenomenon found in the data (Strauss & Corbin, 1998). Researchers periodically met and discussed the subcategories to reach consensus on their meanings related to the categories. This recursive process of discussion and analysis of all interview data initiated development of a coding manual that was used in subsequent analyses. The researchers then engaged in data reduction by recoding data using the coding manual for guidance in comparing and refining categories. Coded categories were collapsed and renamed related to the themes of knowing, teaching, and learning mathematics, as well as beliefs and affect. Data from the belief surveys were considered at the case level by subscale and overall scale. The quantitative data were used for descriptive purposes.

Results

Quantitative Findings

Mean scores, including differences in mean scores, and standard deviations for the two groups of prospective teachers on the MBI and MTEBI (subscales and overall scale) are shown in Table 1. When comparing the two sets of scores, all subscale and overall mean scores have at least half-point differences in the Likert scale value. These findings suggest the prospective teachers in the alternative courses had stronger mathematics teaching efficacy beliefs and pedagogical beliefs that were more cognitively aligned. Two subscales, Teacher and Learner, evidenced the largest differences in mean scores, .77 and .76 respectively. It seems the prospective teachers in the alternative courses, more so than those in the traditional courses, believed that children can construct their own mathematical knowledge and that instruction in mathematics should be organized to facilitate this construction. Interesting, the subscale that revealed the next largest difference in mean score (.70) was the MTOE. When comparing the two groups of prospective teachers, those completing the alternative courses seem to have stronger beliefs that their teaching of mathematics positively influences student learning.

Table 1

Means and Standard Deviations for Mathematics Pedagogical and Teaching Efficacy Beliefs as Likert Scale Values

	Traditional Courses		Alternative Courses		Both Courses
Subscale and Overall Scores*	Means	Standard Deviations	Means	Standard Deviations	Differences in Mean Scores
Learner	3.70	.60	4.46	.49	.76
Curriculum	3.61	.55	4.15	.47	.54
Teacher	3.78	.49	4.55	.32	.77
Overall MBI	3.70	.50	4.39	.31	.69
PMTE	4.08	.23	4.68	.34	.60
MTOE	3.61	.28	4.31	.74	.70
Overall MTEBI	3.90	.13	4.54	.44	.64

*MBI = Mathematics Beliefs Instrument; PMTE = Personal Mathematics Teaching Efficacy; MTOE = Mathematics Teaching Outcome Expectancy; MTEBI = Mathematics Teaching Efficacy Beliefs Instrument.

Qualitative Findings

Traditional courses. The data analysis reveals the prospective teachers characterized the mathematics in the traditional courses as: procedural knowledge, lacking relevance, and difficult. More specifically, mathematics as procedural knowledge included descriptors such as "formulas," "step-by-step," "right and wrong," "abstract," "information," and "definitions," with little attention to processes in mathematics. Mathematics was typified as a *record of knowledge.* Further, the prospective teachers frequently spoke of the irrelevance of the mathematics, describing the mathematics as "high school" or "college" level, with little connection to the elementary classroom. Interestingly, before completing the courses, the prospective teachers believed they already had the mathematics knowledge needed for the elementary classroom; the courses did not challenge the prospective teachers' paradigm about the SCK needed for teaching elementary mathematics. Additionally, the prospective teachers described the difficulty of the mathematics in the courses, particularly as "hard" and "unattainable."

In considering the learning and teaching of mathematics in the context of the traditional courses, it is noteworthy there was little mention of the learning and teaching of mathematics for elementary students. Learning mathematics was characterized as: rote memorization, a process that occurs via experts, and "passing the course." The prospective teachers described their learning through rote memorization as "time-consuming, extensive practice," "note-taking", "homework," and "repetition and regurgitation." Further, this learning took place via receipt from external expert sources, and this expertise included the course instructors, tutors, textbooks, and class notes. Learning was also typified as "passing the course." The prospective teachers spoke of "passing the test" and "getting in and getting out."

The teaching of mathematics in the traditional courses was typified as explaining, and the prospective teachers experienced teaching as "lecturing," "showing," "step-by-step explanations," "Power Points," and "covering content." Further, teaching in the courses was characterized as teacher-centered and content-centered rather than attentive to the needs of the prospective teachers. The teaching was frequently described as "fast-paced," and instructor dispositions, such as differing levels of helpfulness, responsiveness, and availability, were a factor.

The prospective teachers' experiences with knowing, teaching, and learning mathematics were linked with their affective responses in the courses. They described emotional reactions to the courses, including "terrifying" and "frustrating." They also portrayed their experiences as having negative influences on their mathematics teaching efficacy (i.e., beliefs in their capabilities to be an effective mathematics teacher and influence student learning) and mathematics self-efficacy (i.e., beliefs in their capabilities to do mathematics).

Alternative courses. The analysis of the data indicates the prospective teachers portrayed mathematics in the alternative courses as process-focused, useful, challenging, and internally constructed. The process focus included an emphasis on "problem solving" and "understanding," which contributed to flexibility in their mathematical knowledge. The mathematics was also described as "useful" or "relevant," with explicit connections to the mathematics in the elementary classroom. Further, the mathematics was typified as "challenging;" it was a "struggle" for the prospective teachers to "unlearn" mathematics as being simply procedures. Mathematics in the courses was also portrayed as internally constructed (i.e., "in my head") rather than received from other external expert sources. Further, in describing the mathematics in the courses, the prospective teachers frequently contrasted it with the mathematics learned in

other content courses.

The learning of mathematics in the courses was typified in several ways by the prospective teachers. They described learning as occurring through a community of learners, with an emphasis on discourse. Further, learning took place through mathematical processes such as "problem solving," which were portrayed as "engaging" and perceived as "okay to be wrong." Learning mathematics also took place through a focus on children's learning and thinking. The courses built the mathematical knowledge of the prospective teachers by studying how children think about mathematical concepts and ideas; this focus and course assignments led to learning as being perceived as directly applicable to the elementary classroom.

Teaching in the context of the alternative courses was typified by the prospective teachers as "guiding" and "questioning." The instructor promoted discourse, created a safe learning environment, and used tools (e.g., manipulatives) relevant to the elementary classroom. Interestingly, the prospective teachers described a "struggle" or tension in connecting what they were learning in the courses to their teaching in their field placement classrooms, which were often characterized as "traditional." Further, the dispositions of the instructor, such as "helpfulness" and "accessibility," were described as important to teaching in the course.

The prospective teachers' characterizations of knowing, learning, and teaching mathematics were linked with their affective responses in the courses. The prospective teachers described the courses as positively influencing their mathematics teaching efficacy and mathematics self-efficacy.

Concluding Thoughts

More than two decades have passed since Ball and Wilson (1990) challenged the assumptions that: (a) the development of elementary prospective teachers' mathematical content knowledge should occur within the context of traditional undergraduate mathematics courses, and (b) that content knowledge is the only professional knowledge necessary for teaching. These beliefs continue to be espoused by some policy makers and faculty members at institutions of higher education, who believe that prospective teachers need only take additional advanced mathematics courses to acquire content knowledge in mathematics, while disregarding SCK (Sowder, 2007). The prospective teachers' experiences related to knowing, learning, and teaching mathematics, as well as the differential outcomes in beliefs, suggest several benefits of alternative ways of thinking about elementary teacher preparation. Further, the findings provide insights into the issues and challenges of building the SCK needed for teaching elementary mathematics.

It is evident the prospective teachers in this study learned what they had the *opportunity to learn* (OTL) (Hiebert & Grouws, 2007), as revealed in their characterizations of knowing, learning, and teaching mathematics in the distinct course experiences. The Introduction to the original National Council of Teachers of Mathematics (NCTM) *Standards* (1989) states "*what* a student learns depends to a great degree on *how* he or she has learned it" (p. 5, italics in original). OTL is considered a complex process and product of both the curricular emphasis and the quality of instruction (Hiebert & Grouws, 2007). Teacher competencies developed in teacher preparation programs, including SCK needed for teaching mathematics, clearly depend upon how this knowledge is acquired.

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