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Integrating Teacher Candidates' Conceptions of Mathematics, Teaching, and Learning: A Cross-University Collaboration

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Abstract

This study reports findings from an elementary teacher education initiative advanced between a department of mathematics and a school of education in a large, state-supported university. The design incorporated the interconnectedness of teacher candidates' conceptions related to mathematics, teaching, and learning and sought to explore how conceptions related to views of practice. Results suggest that an integrated program can foster an increased willingness to teach mathematics, greater recognition that mathematics is taught in lower elementary grades, a switch in focus of lessons to an understanding of content, and an integration of new content understandings in lesson design.

Introduction

Expectations and ideals endorsed by current reform efforts in mathematics education (e.g., NCTM, 2000) challenge prospective teachers in their thinking about mathematics teaching and learning. Teachers are asked to teach in ways that promote an integrated, connected view of mathematics, rather than a procedural, rule-based view. Research suggests that elementary teacher candidates lack crucial mathematical knowledge and conceptions needed to support this approach to mathematics teaching (Frykholm, 2000; Ma, 1999). Although this climate provides an exciting opportunity for teacher educators of both content and pedagogy, there is not a clear path as to how to integrate these two historically separate facets of teacher education to promote prospective teacher learning that challenges mathematical understandings and beliefs (Ambrose, 2004). Students often leave their teacher education programs with the same preconceived notions about content, teaching, and learning as when they enter; thus, some of these programs constitute a weak intervention (Kagan, 1992; Seaman, Szydlik, Szydlik, & Beam, 2006). One contributing factor to students leaving with similar knowledge and beliefs is that many teacher education programs, particularly at the elementary level and in mathematics, do not connect across content, method, and general pedagogy throughout the entire program (Ishler, Edens, & Berry, 1996).

Teacher preparation is further complicated by the Federal- and state-level expectations for teachers to become Highly Qualified (No Child Left Behind, 2001). Mandates make it imperative for all teachers to have an opportunity to work toward initial and continuing certifications within a unified program and place emphasis on content knowledge, with mathematics being identified as a paramount component of elementary teachers' content foundation (U.S. Department of Education, 2003). Given this situation, teacher education programs must simultaneously place content knowledge as paramount in the design of program.

This paper describes our response to this critical time in teacher education. Specifically, we generated a theoretically grounded initiative to facilitate connections between content and pedagogy by challenging teacher candidates' conceptual understandings and views toward mathematics, teaching, and learning. This re-conceptualization of program design is the result of our efforts (two teacher educators–one in a department of mathematics and one in a school of education) to integrate mathematics content, general pedagogy, and mathematics methodology courses. Although students in elementary education programs traditionally take courses in mathematics, general pedagogy, and mathematics education, often these courses do not systematically stress conceptual understanding of content and its connection to the teaching of mathematics, which is the central focus of current K-12 reform efforts (e.g., NCTM, 2000) and government mandates. Furthermore, many programs do not make conceptual understandings explicit enough to challenge previous misconceptions and beliefs of mathematics (Borko & Putnam, 1996). They do not place these new understandings of mathematics within the larger context of being a teacher (e.g., Ball, Lubienski, & Mewborn, 2001).

In this paper, we report findings about the transformation of teacher candidates' conceptions and reflect on the important role that program goals and structures played in that process. We are defining *conceptions* to include a teacher's knowledge, beliefs, and understandings about mathematics and mathematics teaching which frame his or her thinking and decision-making as it relates to practice (Lloyd & Wilson, 1998). To accomplish our aim we investigated the following question: *What changes occur in teacher candidates' conceptions toward mathematics, toward teaching, and toward learning during their tenure in this program?*

Theoretical Framework

Throughout our experiences as teacher educators we, like many others, watched our students struggle with how to balance their mathematical anxiety and narrow view toward mathematics with their professed desire to teach in ways that allow for conceptual understanding of subject matter and active learning (Borko, Davinroy, Bliem, & Cumbo, 2000; Thompson, 1992). Often in mathematics methods courses teacher candidates claim to have developed knowledge and beliefs that support the current reform efforts; however, during practice teaching they struggle to enact their stated ideals and often revert to practices that are aligned with their deeply held conceptions (Wilson & Goldenberg, 1998).

Beliefs that teachers hold during their schooling years are difficult to change (Philipp, 2007). Research on teacher change indicates that programs can facilitate changes in teachers' thinking within the context of educational reform (e.g., Richardson & Placier, 2001). As Kagan (1992) noted after observing pre-service teachers, "If a program is to promote growth among novices, it must require them to make their pre-existing personal beliefs explicit; it must challenge the adequacy of those beliefs; and it must give novices extended opportunities to examine, elaborate, and integrate new information into their existing belief system. In short, pre-service teachers need opportunities to make knowledge their own" (p. 77). This paper acknowledges the interconnectedness of beliefs related to mathematics, teaching, and learning, and attempts to make sense of how these beliefs connect to knowledge and practice, thus ultimately impacting candidates' ability to expand their vision of mathematics teaching. Our study therefore uniquely contributes to the literature on teacher development and change through the integration of this complex relationship in both program and research design.

As noted earlier, within teacher development programs a teacher's content knowledge is critical and must be placed as priority. Hill, Rowan and Ball (2005) found that "teachers' mathematical knowledge was significantly related to student achievement gains" in elementary classrooms (p. 371). However, programs must examine the type of mathematical content that is explored, as well as the explicit links they make to pedagogy. Ball and colleagues (2001, 2005) cite the importance of *knowing mathematics for teaching*, which encompasses all of the knowledge required to teach mathematics effectively. From a programmatic standpoint, this perspective suggests that programs should provide opportunities for prospective teachers to learn mathematics around specific content and teaching situations that may arise in their future practice. Consequently, they urge teacher education programs to study how differences in integrating all areas of knowledge (pedagogy, mathematics, teaching of mathematics) influence teacher learning and ultimately student achievement (Ball, Hill, & Bass, 2005). With this study of our integrated initiative we aim to begin to respond to this "contemporary challenge" (p. 45).

Our overarching goal is to improve the effectiveness of mathematics teaching as it impacts student learning by focusing on the link between our integrated program and teacher candidates' learning. Research suggests that teachers can serve as the primary catalyst for change in students' learning (Borko & Putnam, 1996). Furthermore, it is our belief, and the finding of many studies, that effective teacher development can be an invaluable foundation for high-quality, reform-oriented teaching that leads to improved student achievement (e.g., Darling-Hammond & Youngs, 2002). As Darling-Hammond (2000) urged, "…teacher preparation and certification are by far the strongest correlates of student achievement in reading and mathematics," (p. 27).

This study examined candidates' conceptions, which included both knowledge and beliefs. For example, teachers' content knowledge must be flexible enough to allow them to make connections, conjectures, and validations of ideas (Anderson, 1989; Borko, 2004). Research suggests that teachers' knowledge of and beliefs about mathematics are related in powerful ways (e.g., Putnam, Heaton, Prawat, & Remillard, 1992; Wilson & Cooney, 2002). Lloyd and Wilson (1998) suggest that flexible and well-organized conceptions are necessary to implement mathematics teaching that is aligned with reform ideals.

Furthermore, a teacher's knowledge of general pedagogy has not been historically acknowledged as critical in building effective mathematics practice (Hiebert, Morris, & Glass, 2003). We conjectured that general conceptions about teaching and learning were intimately connected to candidates' views of mathematics and mathematics teaching, and therefore our project highlighted the richness and eventual impact of this symbiotic relationship. Our effort addressed the connections between pedagogical and content knowledge early and jointly within the elementary education program experience at our then common university. Building on the work that other researchers have done within an integrated approach to program (e.g., Hubbard & Abell, 2005), we have provided our students with models of what conceptually-based instruction looks like, as well as opportunities to understand mathematics within a teaching context through a blending of both content and method early and consistently within our across-university experience.

Context

This study took place at a large, mid-western university serving over 17,000 students. With more than 300 elementary education undergraduates graduating per year, the elementary education program is considered a substantial program both within the university and across the country. Within the required elementary teacher education courses, there were three primary courses within which we focused our efforts related to mathematics education reform: a mathematics content course (Math), a pedagogy course in general instructional design and assessment (Ed), and a mathematics methods course (Method). These courses represented our university's commitment to cross-departmental education; the two methods courses were offered in our School of Education, while the content course was offered within the Department of Mathematics and Statistics in the College of Arts and Sciences.

The goal of our initiative was to create an integrated, elementary teacher education program that addressed and developed teacher candidates' conceptions of mathematics, teaching, and related to learning as a systemic objective. We aligned previously disconnected courses in mathematical content, general pedagogy, and mathematics methodology throughout the required mathematics strand. By linking the goals for our, the primary investigators', courses (*experimental sections*) early in the professional development sequence, we sought to build a conceptually-based lens toward teaching and learning that could frame teacher candidates' entire program. We sought to combat the traditional dilemma faced in one-semester mathematics methodology courses, primarily not having enough time to foster new conceptions. Additionally, we recognized the need to address and develop teacher candidates' beliefs and knowledge as a systemic objective earlier in, as well as throughout the program and across units. Using the mathematics strand as the content context, we anticipated that teacher candidates' general views about teaching and learning would be simultaneously influenced.

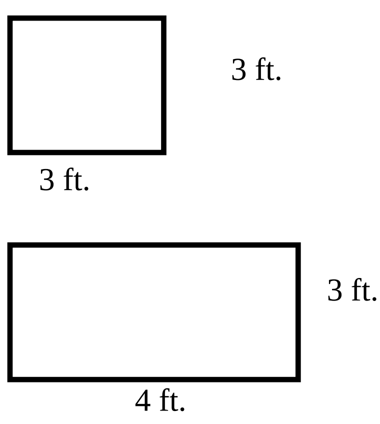
Teaching the same group of elementary education students provided us, the authors and researchers, the unique opportunity to consistently develop teacher candidates' thinking on our shared views, which then served as the foundation from which we generated course goals. These goals included active knowledge construction, opportunities for on-going reflection, a focus on enduring mathematical understandings, modeling teaching practices that support these tenants, as well as aligning course goals with authentic activities (e.g., Stein, Smith, Henningsen, & Silver, 2000).

Sample course activities

We designed activities for all experimental sections to challenge existing conceptions and facilitate beginning recognition of the connection between being a learner of mathematics and a teacher. For example, in Math teacher candidates developed a Mathematics Project (see Figure 1) that promoted attention to underlying K-8 concepts as addressed in the NCTM Principles and Standards (2000) that are typically difficult for students.

Figure 1*: Math—Sample Mathematics Project Question*
This question appeared on a survey developed as part of the RADIATE (Research and Development Initiatives Applied to Teacher Education) Project funded by the Eisenhower Foundation.

Imagine that one of your students comes to class very excited. Susan explains that she has discovered that as the perimeter of a rectangle increases the area also increases. Susan shows you this picture to prove what she is saying:



perimeter = 12 ft.
area = 9 square ft.

perimeter = 14 ft.
area = 12 square ft.

(a) Argue whether or not Susan is correct. Be sure to provide a clear and thorough explanation with examples.

(b) How might you then respond to Susan? Try to be specific and include examples, if relevant. For example, you might discuss what you would say to Susan, examples you would provide her, and/or how you might then follow-up with the whole class.

The goal was to collaboratively explore concepts central to this course (e.g., problem solving, fractions, base number systems) through activities that linked candidates' growing understandings to thinking about how they will teach.

In Ed, teacher candidates generated an Authentic Unit Design in which scaffolded assignments led to the creation of an authentic unit incorporating the content standards outlined in their state's curriculum framework (see Figure 2). In this activity candidates were required to use their knowledge of mathematics to determine what specific concepts and skills they wanted students to learn with their unit, as well as align their choices and parallel assessments with state, and therefore national, recommendations for both content and pedagogy.

Figure 2*: Ed Course—Scaffolded Project Example*

The purpose of this series of assignments is to enable prospective teachers to design instruction and assessment that promote enduring understanding. This work will be based on approaches discussed in class, including backwards design as elaborated in your text, *Understanding by Design* (Wiggins & McTigh, 2005).

<u>Assignment #1</u>
Choose a state curriculum standard. Explain the desired results (understandings, knowledge and skills) students must have to meet that Benchmark and Standard.

<u>Assignment #2</u>
Describe an authentic assessment you can use in your classroom that will provide you evidence that your students meet your desired results outlined in Assignment #1.

<u>Assignment #3</u>
Design an authentic unit of study that focuses on conceptual understanding. This unit should include all lessons and artifacts that will enable students to achieve your desired results (Assignment #1) as evidenced by your generated assessment in Assignment #2

As part of our program we consciously linked these courses. This integration centered on using consistent language to describe both aspects of content and pedagogy, making explicit the connections between being a learner of content and a teacher of that same content, and requiring candidates to utilize what they had or were simultaneously learning in Math to design the final unit in Ed. We strove to accomplish the following goals: (1) help candidates use new understandings of concepts to solve problems as learners of mathematics, (2) facilitate candidates' understanding of how to design instruction that promotes conceptual understanding as prospective teachers, (3) provide opportunities for reflecting on and discussing how to connect understandings of mathematics and pedagogy to practice, and (4) assist candidates in the on-going process of how to examine their growing conceptions and pedagogical choices.

Participants and Data Sources

Participants were elementary education students, with Table 1 delineating number of participants in each course, including differences among experimental and non-experimental sections. Within the content course (Math) and general pedagogy course (Ed) we taught certain sections (referred to as *experimental*, or "E"). Sections taught by other full-time faculty are referred to as *status pro quo*, or "S." While some participants participated in E sections for both courses, others were only in one E section, and a final group ended up in

S sections for both courses. In *Results,* we discuss findings relative to these sorted groups within the first year only (3 semesters) of the study. Findings relative to the mathematics methods course are explored in another paper.

Table 1: *Number of Participants by Course and Semester*

	Semester (Fall)	Semester 2 (Winter)	Semester 3 (Spring)	Semester 4 (Fall)
Math (E)	**60**	**56**	XX	XX
Math (S)	**73**	**32**	XX	XX
Ed (E)	**41**	**42**	XX	XX
Ed (S)	**54**	**52**	**28**	XX
Method (E)	XX	XX	XX	**72**

Primary data sources included: beliefs surveys, content exams, course artifacts, and interviews. Belief surveys (Likert-type scale [1-5] and open response questions) were distributed to participants in all sections at the beginning and end of Math and Ed. All students regardless of section type (E or S) received the same surveys. Math and Ed surveys differed slightly, as they attempted to garner information about beliefs specific to the type of knowledge in the course. The Math survey collected information about participants' overarching conceptions related to mathematics and its teaching. The Ed survey asked participants to elaborate conceptions about teaching and learning. Questions included: "Mathematics involves mostly facts and procedures to be learned," and "It is important for teachers to have a thorough understanding of the subject he/she is teaching."

End of course surveys were similar to beginning surveys. We additionally asked participants to reflect on their experiences related to specific activities, and how courses may have influenced their conceptions. Administering surveys at the beginning and end of these courses allowed us to interpret changes in individual participants' conceptions, compare across individuals throughout the program, and compare between E and S sections.

Content exams were administered at the beginning and end of all Math sections to better understand participants' background preparation of and growth in understandings. End of course final exams differed for each section, with the experimental section exam providing more opportunities for participants to explain their understandings and articulate how their knowledge of mathematical concepts connected to how they will teach those concepts. Research artifacts included course assignments, teacher-researcher course notes for experimental sections, and researcher journals.

At the end of the first year, we conducted semi-structured interviews with a subset of participants (those who were in E sections for both courses and volunteered participation) to gain a richer understanding of participants' conceptions. All interviews were audio-taped and transcribed. The goal here was to make sure that we had interpreted their survey responses correctly and had arrived at a common ground. Additionally, we wanted to learn more about motivations behind responses, particularly those responses that were different from the norm.

Analysis: Three Phases

Phase One

We analyzed qualitative data using *direct interpretation* (Stake, 1995) to illuminate emergent themes and patterns to understand the substantive changes in teacher candidates' thinking. For example, coding illustrated what changes occurred in participants' conceptions of mathematics, teaching, and learning.

In Table 2 we provide coded categories with participant examples that later link to ideas presented in results.

Table 2: *Coded Data Examples*

Research Question Themes	Coded Categories	Examples from Data
Mathematics	(1) Views of mathematics as a discipline (2) Views of mathematics teaching and learning (3) Conceptual understanding of mathematics (4) Disposition toward mathematics	(1) Math involves mostly facts and procedures that have to be learned [commonly selected pre-survey item in most sections of Math] (2) "Math can be difficult for some people, and a few never catch on." [Math (E), post-survey] (3) "I have a better understanding of why we can do certain things in math, i.e., cross multiply." [Math (E), post-survey] (4) "Math is still challenging, but it now seems fun." [Math (E), post-survey]
Teaching	(1) General views of good teaching, including assessment (2) Understanding of importance of content (3) Disposition toward teaching	(1) "Subjects can be made into fun projects." [Ed (C), post-survey] (2) "I think that subjects that I have a greater understanding in will be easier for me to teach." [Ed (E), post-survey] (3) "A good teacher is a life-long learner." [Ed (E), post-survey]
Learning	(1) General views of how students best learn (2) Understanding of the role of the teacher in learning process (3) Recognition of the importance of their learning experience in future practice	(1) "Hands-on learning is best, except for math." [Ed (E), course artifact] (2) "If the content of the subject is boring to the teacher, she is not going to present the subject in an exciting and unique manner." [Ed (C), post-survey] (3) "I now see that understanding division at a deeper level will allow me to better explain and show examples for problems, especially those with fractions." [Math (E), course artifact]

To analyze change, we calculated means and standard deviations on content exams and percentage responses on multiple-choice beliefs survey questions; relevant quantitative findings are provided in *Results*.

Phase Two

We *aggregated* (Stake, 1995) data across individuals to glean growth in understandings within each course. From this process we generated *guiding principles* that served as a frame to make comparisons within and across sections. Additionally, we kept analysis at the individual level so that case studies could be generated throughout the program experience.

Phase Three

We used results from the second phase to make comparisons among course sections; we paid particular attention to experimental versus control sections. In essence, we conducted analysis at three levels: individual student, course section, and program design. Within this final stage we also compared researchers' findings revealed through course notes and journals to what was learned in analysis related to the first research question. This process helped us to cross-validate themes generated initially in phase one and reflect on the whole program.

We addressed issues of validity and reliability by performing the following: (1) triangulated data by using multiple sources, (2) coded data independently (two researchers), allowing for cross-validation of results (inter-rater reliability resulted in 92% agreement), (3) verified our interpretations using *member-checking* (Stake, 1995), and (4) coded systematically and inherently through the multi-stage nature of the research project.

Results

We organize results around our research question: *What changes occur in teacher candidates' conceptions toward mathematics, toward teaching, and toward learning during their tenure in this program?* Within this question we elaborate *guiding principles* that encompassed the ideas, each including multiple understandings related in complex ways, which appeared most frequently and significantly throughout the analysis of data.

Results suggest that most (~85%) of the candidates in E sections changed their conceptions toward mathematics, teaching and learning. Four guiding principles illuminate this change: (1) *Understanding of the connection between content and practice*, (2) *Views of mathematics as a discipline*, (3) *Translation of the learning experience to practice*, and (4) *Affective perspectives toward mathematics, teaching, and learning*.

Understanding of the Connection Between Content and Practice

Within this first principle, three participant ideas became salient: (1) recognition that their own content knowledge will impact how they will teach that content, (2) inclusion of content knowledge as a focus of their instruction, and (3) understanding that content knowledge is a central attribute of being a "good" teacher. Related to the first idea, participants in E sections recognized that their own understanding of content is critical to the design and implementation of instruction. As one participant stated, "We all have different ideas about different subjects, and everything we teach will be influenced by our own understandings and beliefs about that subject," [Ed (E), post-survey]. This revelation was echoed by many students during class and within Ed assignments. As one participant actively bellowed in class while trying to complete her unit plan on operations with integers, "Oh, [shoot], I guess I have to really understand this before I can finish this plan," [teacher-researcher journal, Ed (E)]. She, like many others, came to recognize that her lack of content understanding inhibited her ability to complete a lesson plan that was aligned with reform suggestions.

Even during E sections of Math participants commented on the need to understand content in flexible ways to best help their students understand these concepts. As one participant stated, "The more methods and strategies I learn in problem solving, the easier it will be to get concepts across to students," [Math (E), post-survey]. This idea was most often articulated within a mathematics education project and on end of course surveys. For example, one participant expressed, "I think that since I have a better understanding of why certain things are done to solve a problem, I'll be able to teach it more effectively," [Math (E), post-survey]. Similarly, upon completing their intensive, mathematics education projects in the experimental Math sections, participants (87%) commented in project reflections that it was only through gaining a deeper understanding of concepts (e.g., division with fractions, modulo arithmetic, relationship between area and perimeter) that they were able to begin to think about how to facilitate students' learning of the same mathematical concepts.

Contrastingly, on end surveys in Ed and Math S sections, participants did not articulate the importance of understanding mathematical content as central to effective instruction. This finding was particularly evident among participants who were in S sections for both courses. For example, in response to the Ed end survey question, "Do you envision that how you will teach a subject will be influenced by the content of that subject?", typical responses included: "No, because we as teachers need to make all subjects fun," "Yes, if it is a subject or something I am more interested in, I will teach it more enthusiastically," and "Even the driest of content areas can be made interesting." What we find notable is that participants spoke more to the fun and interest aspects of teaching, rather than directly commenting on content knowledge, which is what the question addressed. These types of comments from S group participants suggest that they did not come to appreciate the important role that their own understandings of content can play in their practice, thereby indicating no change in perspective compared to beginning of course surveys. The small percentage (8%) of participants in S sections who did address content knowledge in post surveys did so at the beginning of course as well.

In addition to recognizing the importance of content understanding of the teacher in instruction, E section participants, particularly in the Ed course, also came to refer to their future students' understanding of content as being a primary goal of instruction. On early Ed course assignments in both S and E sections participants viewed the goal of a lesson to be to keep students "engaged," and "having fun." Their words reveal concern over students' motivation. Within the final project assignment in E sections, participants' comments included references to their students' understanding of content. As one participant noted, "I think that these lessons will give the students an understanding of what was really happening during World War II. The lessons go deeper into the truth about the Holocaust, rather than merely focusing on facts and dates." In her reflection she not only acknowledges her attention to students' understanding, but she also describes an understanding of historical themes as opposed to a superficial knowledge of facts. This statement, exemplary of many others, reveals growth in recognition of the importance of thinking about students' understanding in planning, as well as what level of understanding is expected by state expectations.

The third idea embedded in this principle is that by the end of Ed course activities in E sections, participants also saw content knowledge as being an important attribute of a "good" teacher. This reflected a dramatic change from themes during the beginning of all sections; most participants only referred to affective attributes, e.g., "caring" and "loves children." What we find compelling about this finding is the integration of content into the E section participants' views of what being a teacher embodies. Typically elementary education students think first about the *practical* aspect, or doing, of teaching, which is then separate from how they view themselves as teachers of children. Even with greater focus on teaching content in E sections, we were pleasantly surprised that many participants were able to integrate the experience in ways that allowed for a transformation in their personal view of themselves as teachers, and therefore what the role of a "good" teacher is. It became evident that this shift in view of the teacher corresponded with participants' ability to more fully conceptualize lessons around important mathematical concepts.

Views of Mathematics as a Discipline

The second principle conveys that participants changed their views of mathematics as a discipline. For example, many participants who understood mathematics as static and comprised of rules to be memorized later described mathematics as complex, changing, and open-ended. This reform perspective of mathematics premised course goals and activities in E sections. By the end of Math, almost all participants in E sections referred to mathematics as using multiple approaches and as necessary to solve problems in real-life situations. As one participant stated, "I now [after taking this course] realize there are different ways to approach problems," [Math (E), post-survey]. This participant conveys here that he now recognizes that there are multiple ways to solve problems; the focus is now on the process of finding a solution, rather than the answer. Echoing this view, another participant stated, "I learned that simple math that we learned in elementary school can be broken down into so many different ways to come up with answers because everyone has different methods to find answers," [interview]. Given E section participants' growth in content understandings that paralleled this expanded view of mathematics, as measured by a comparison of content exams, we concluded that these participants' enhanced content knowledge impacted their developing conceptions related to mathematics. Changes in conceptions were less evident in S sections, as measured by % of change on surveys, as well as growth in understandings on Math final exams.

Within S sections participants spoke less of mathematics as a problem-solving endeavor. One participant remarked that mathematics was computation, "because math is mainly computing numbers and variables," [Math (S), post-survey]. Another participant stated, "Math is numbers that if they are put together the correct way, they will give you a correct answer," [Math (S), post-survey]. As both quotations suggest, to most participants in S sections their views of mathematics had not moved beyond thinking of procedures, answers, and computation. This perspective is typical of elementary education students entering content courses. Our program explicitly addressed these views of mathematics, teaching and learning early and throughout. As a result, in E sections of Ed, participants questioned both their own content understandings and views of mathematics as a subject.

Translating the Learning Experience to Practice

The third principle related to participants' realization that their learning experiences in the E Ed and Math sections were different than previous learning experiences and they intended to integrate what was modeled in their future practice. One example is *explanation* required by participants in Math E sections. Participants were required to explain their thinking about mathematical concepts both within class discussions and on assessments (e.g., project, exams). Data revealed that participants began articulating that they considered their ability to now explain mathematics as central to their future practice and would require their own students to explain the process of solving problems. As one participant noted on her end of course survey and elaborated during an interview, "This course was the first one that made me really think about mathematics. Trying to explain my thinking was difficult, but I now see that it is necessary to really understanding math. Although I don't think most elementary teachers do this, I hope to make my students explain their reasoning." This participant's comments exemplify what most E section participants came to realize: mathematics is solving problems and that teachers must scaffold this process.

Within Ed, E sections *focus on and use of authentic assessment* became an integral experience that participants then indicated they would translate to their future teaching. On early assignments and surveys, participants referred to "effort" and "positive student affect" as important considerations in creating assessments. Specifically, on a Likert-type scale [1-6] pre-survey question that asked, "Effort should be a major consideration when grading students," the mean score for all participants in Ed courses was 5. When asked this same question again on the end survey, the mean for participants in E sections decreased to 3. Simultaneously, on the question that asked, "To assess students' understanding it is important to observe them and listen to their conversations," E section participants' mean increased from 3 on the pre-survey to 5.8 on post. These findings suggest that some participants realized the multi-faceted and complex nature of assessment. Specifically, the means on these two questions reveal that E section participants' understanding that in their own practice they will need to make evaluations of students based on more than affective factors. End of survey comments to open-ended questions further reveal that some participants in experimental sections believed that students' content knowledge is part of their expanded view of assessment. As one participant expressed, "Assessment allows the teacher to determine if a concept is fully understood by a student before moving on to other concepts," [Ed (E), post-survey]. This statement reflects a more content-driven curriculum, which emphasizes the centrality of student learning.

Affective Perspectives Toward Mathematics, Teaching and Learning

The final principle relates to how participants *felt* about mathematics and their ability to teach mathematics. It has been well documented that many elementary teachers suffer from mathematical anxiety, which can then impact how they teach (e.g., Weinstein, 1990). Our data echoes this finding; most participants in all sections expressed high levels of mathematical anxiety when entering the Math course. Common examples included, "Math is really hard and takes more effort to learn other subjects," [Math (E), pre-survey], and "Math is a phobia," [Math (S), pre-survey]. As these comments suggest, many participants in all sections communicated fear and a feeling of being overwhelmed when trying to do and be successful at mathematics. It was of interest to us that most of these participants simultaneously indicated that mathematical ability is an innate "gift," that some people either have or do not. Most participants (78%) considered themselves in the "do not" category and therefore had low self-esteem relative to their abilities. They therefore expressed doing mathematics as being a "difficult," "challenging," "scary," and "frustrating" endeavor.

It was not surprising that paralleling this finding was the indication from all participants that they were not confident in their ability to teach mathematics. Many participants expressed the decision to teach in the lower elementary grades, indicating their (albeit false) belief that they could avoid teaching mathematics altogether by leaning toward earlier grades. Comments such as, "I don't really need to understand fractions, because I'm going to be teaching kindergarten or first grade," [Math (E), teacher-researcher course notes], and "I don't need to do a math unit, because I'm going to teach kindergarten," [Ed (E), teacher-researcher journal], illustrate participants' perspectives relative to the relationship between a teachers' content knowledge and choices in practice. This finding relates to the first two principles as participants' fear toward mathematics resulted in avoidance of teaching mathematics, thus dictating professional choices. What we find problematic is that all of our students are certified to teach all subjects in grades K-5. The intent of the Highly Qualified mandates is that teachers have content understandings appropriate to teaching all grades within their certifications. We find it also of concern that embedded in participants' statements is the misconception that no mathematics work beyond perhaps knowing and counting numbers is taught within lower elementary grades.

Within E Math sections we made overt efforts to identify and address participants' anxieties and inaccurate perceptions toward mathematical ability. By the end of E sections, the majority of participants (95%) began expressing that they felt more confident in their ability to do, as well as teach, mathematics. Many specifically noted that understanding mathematics was a realistic goal.

By the end of the Ed course, participants in E sections began conveying the importance of a teacher's understanding of content on artifacts/surveys, again reinforcing movement toward their recognition of views explained in Principle One, namely that content knowledge is central to pedagogy. Data revealed that participants in E sections for both Ed and Math courses more clearly identified this change in perspective during interviews, suggesting that having more experience talking about and reflecting on these issues provided them the language to express their thinking.

Discussion

Existing research has not sufficiently studied the programmatic benefit of early and joint integration of mathematical, pedagogical, and pedagogical content knowledge throughout an elementary teacher education experience. Teaching the same group of elementary education students throughout the program allowed us to uniquely integrate and examine the early professional development of teacher candidates. We began our work in response to two layers of concern within our teacher education program: new state and Federal demands for enhanced content knowledge, particularly in mathematics, and a desire to change teacher candidates' conceptions. While we did not change the course sequence structure of the existing program, our re-conceptualization provided a linked, clearly articulated framework that placed the connection between content and pedagogy as central.

Our findings describe the transformations in conceptions that occurred after prospective teachers experienced this integrated program. These changes manifested in three primary areas: (1) enhanced understandings of mathematics, (2) the translation of modeled experiences into ideas about future practice, and (3) changes in affective attitudes toward mathematics. All of these changes impacted participants' ability to understand the important role that what they know and believe about a subject, particularly mathematics, plays in their decision-making about practice. As a result of changes in conceptions these teacher candidates expressed an increased willingness to teach mathematics, greater recognition that mathematics is taught in lower elementary grades, a switch in focus of lessons to an understanding of content, and an integration of new content understandings in their lesson design. Changes in prospective teachers' conceptions are important to their future practice, because how teachers understand content and pedagogy impacts whether or not they can implement reform recommendations for best practice (e.g., Ball, Lubienski, & Mewborn, 2001; Stipek et al., 2001).

Believing in Myths

As noted in *Results*, many participants began the program believing in many *myths* about mathematics, teaching, and learning. Barlow and Reddish (2006) speak to *mathematical myths* (e.g., "some people have a math mind and some don't," "there is a best way to do a math problem," and "math is not creative") in their article on preservice teachers' beliefs. As they accurately note, believing these myths can prove to be detrimental to learning both mathematics and how to teach mathematics. Our study expanded this work by also looking at prospective teachers' myths related to aspects of general pedagogy (e.g., being a good teacher means loving children) and learning (e.g., learning should be fun). For example, many of the participants in our study expressed that little mathematics, if any, is taught in lower elementary grades and that they can therefore avoid teaching mathematics, which they find to be difficult and frustrating to understand, by teaching in the lower grades. This myth, namely that content is not explicitly addressed in lower grades, served to act as a crutch for our students, helping them to avoid what they perceived to be a difficult learning situation. While teacher candidates in experimental sections gained content knowledge, confidence in their ability to do and teach mathematics, and experiences working with mathematics content expectations for lower elementary grades, remaining participants may have left our program with an inaccurate impression about school mathematics.

We believe that elementary teacher education must explicitly examine teacher candidates' knowledge and beliefs related to content and pedagogy and incorporate what is learned in individual courses, as well as overall program design. Specifically, more work is needed that explores programs that overtly challenge the plethora of myths that many elementary education students hold. It will be impossible for teachers to reach the level of competency profited by national reforms (e.g., NCTM, 2000) and mandates for content knowledge (e.g., No Child Left Behind, 2001) if they do not recognize content as existing in the curriculum, understand the central role that content knowledge plays in practice, and acknowledge that they must have flexible enough content understandings that will allow them to teach all content areas within all grades in their certification.

Lessons Learned–Necessary Conditions

Findings presented here will help to advance the conversation about how to prepare elementary teachers to teach content, specifically mathematics. This study suggests that integrated programs that combine non-traditionally connected units can facilitate changes in teacher candidates' conceptions. We were fortunate that certain university structures were already in place that helped to facilitate program connections and collegiality. Through this experience we learned that the process of making change within our elementary teacher education program was successful because it was supported on two levels–faculty and greater-university. Our project began as a ground-up process; we were two colleagues brainstorming about how to improve program. Our common theoretical framework provided a unified lens through which we developed a new approach to program design and parallel research study. The university had not identified the mathematics strand within the elementary education program as an area needing improvement; therefore, our vision and perseverance toward creating and implementing this project served as the primary impetus for change.

However, while our endeavors are notable, the implementation of our ideas could not have been possible without the support of many individuals within the university. For example, at the unit level, both of us received the academic freedom to make changes to courses, as well as support in distributing and collecting artifacts for data collection. Additionally, one of the researcher-authors of this paper holds a joint appointment in both a school of education and department of mathematics. This existing, visionary structure provided an immediate vehicle through which we could easily collaborate, link program goals, as well as communicate with faculty and administrators in both units.

What we also learned was that when programs are purposely designed to understand and address students' thinking about content and pedagogy early and connectedly in a program, changes can be made in mathematical conceptions that will ideally lead to conceptually based teaching. Our shared belief that content and pedagogy are both necessary and share an important relationship to each other and future practice was evident in the design of all experimental section assignments, discussions, and in-class assessments. This approach extends the work of Ball and colleagues (2001, 2005), as it explicitly addresses elementary education students' concern over issues of general pedagogy (e.g., loving children, caring for students' needs, making learning fun) and incorporates this realization into the design of program. As Sztajn (2003) found in his study of practicing elementary teachers, "Teachers' values and expectations are connected to their perceptions of students' lives and needs," (p. 71). While teachers try to provide students with what they believe is best for their students, teacher education programs must help them to understand the importance of integrating content knowledge into their teaching conceptions. Studies that include observations of practicum experiences within integrated programs would further this work by investigating exactly what types of support prospective teachers need as they begin their practice with enhanced conceptions.

We believe that the words *early* and *connectedly* are also critical. As research suggests, change takes time. Teacher candidates must begin to experience this approach early in their coursework, as well as consistently throughout the mathematics strand. As noted in the discussion of the fourth principle, participants in the E/E subset of the study more fully articulated their recognition of the connection between content and practice, which reflected our overarching program goal. This finding suggests that the consistency of framework appeared to play a crucial role in participants' growth in understandings. What must still be explored is how to establish this type of university structure that we found to be necessary to achieve our program goals. This research provides an important contribution to existing teacher education literature as it examines the outcomes of a historically unique program that has placed at the forefront the reality of current mandates related to mathematical content knowledge and reform-oriented teaching expectations for teachers.

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