

CATALYZING CHANGE IN PROSPECTIVE TEACHERS' ORIENTATIONS:  
BUILDING ON BELIEFS ABOUT CARING

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## ABSTRACT

Prospective teachers come to their teacher education programs with beliefs that result from their experiences as students in schools. Often teacher educators consider these beliefs to be wrong or naïve and seek to challenge them so prospective teachers will reject them for more generative beliefs. Because of the resilience of prospective teachers' beliefs in response to these challenges, teacher educators need to develop alternative ways of thinking about and addressing beliefs. The potential of a carefully engineered early field experience to build upon rather than tear down prospective teachers' preexisting beliefs is explored. To extend earlier characterizations of belief systems, I, in developing a theory of belief change, emphasize the position of preexisting beliefs as foundations for an emerging belief system. A case study is used to show how the caring orientation of one prospective teacher served as a generative foundation for belief change when it moved her to reconsider her assumptions about how children learn mathematics and to revise her beliefs about teaching mathematics. Four components of the field experience are identified as critical to catalyzing the belief system change that is described.

**Key Words:**

Caring in Teaching, Early Field Experience, Prospective Teachers' Beliefs, Teacher Preparation

**Abbreviations:**

MEFE – Mathematics Early Field Experience

IMAP – Integrated Mathematics and Pedagogy Project

CATALYZING CHANGE IN PROSPECTIVE TEACHERS' ORIENTATIONS:  
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Prospective teachers come to their teacher education programs with a variety of beliefs that result from their experiences as students in schools. They believe that teaching will be relatively straight forward consisting primarily of offering clear explanations to children. They tend to believe that the bulk of their learning will be in their student teaching placement rather than in their university subject-matter-specific coursework (Book & Freeman, 1986). On the one hand, most prospective teachers assume that teachers' subject-matter knowledge is much less important than their ability to relate to children and manage a classroom. Weinstein (1989) characterized this orientation as an *optimistic bias* because prospective teachers enter their course work assuming that they already know what they need to know in order to teach (Feiman-Nemser & Buchmann, 1986). Often these beliefs serve to limit prospective teachers' engagement in the university coursework designed to enhance their subject-matter knowledge.

Mathematics educators, on the other hand, believe that teachers' subject-matter knowledge is extremely important. Mathematics educators have documented the limited content knowledge of prospective teachers (Ball, 1990; Ma, 1999), and universities require courses that are expected to enhance prospective teachers' mathematical knowledge. These courses are often designed to have prospective teachers make sense of the mathematics and understand the principles that underlie the arithmetic they memorized as children. Despite the promising design of the courses, prospective teachers' beliefs about mathematics and teaching often mitigate the effects of the courses. The prospective teachers' disinterest in subject-matter knowledge, accompanied by their conceptions of teaching and learning, interfere with their learning mathematics in the ways their university instructors would like.

In addition to beliefs about subject matter, prospective teachers hold beliefs about the work of teachers. Specifically they believe that the most important attributes of good teachers are that they be caring and warm, giving top priority to promoting children's self-esteem (Weinstein,

1990). These beliefs may be more central and more enduring than beliefs about subject matter, and they are unlikely to change in either their intensity or prominence. Practicing teachers' definitions of good teachers focus on the same interpersonal attributes (Weinstien, 1989). In this paper I will present an argument in favor of tapping into prospective teachers' strong beliefs about promoting children's self-esteem as a catalyst for revising their belief systems in regard to both mathematics and teaching mathematics.

To make this argument, I will describe an early field-based experience, a part of the Integrating Mathematics and Pedagogy project (IMAP). In this description I examine the beliefs that prospective teachers bring to the field experience and consider these experiences as foundations to be built upon rather than as barriers that have to be torn down. Specifically I develop a case that shows how one prospective teacher's interest in relating to children proved to be a catalyst for expanding her views of teaching and her beliefs about learning mathematics.

## BELIEFS

### *Generative Beliefs for Learning Mathematics*

In considering how to reorient prospective teachers to mathematics, we, the IMAP researchers, have hypothesized about the beliefs that might grow out of the prospective teachers' IMAP experiences, beliefs that would lead prospective teachers to approach mathematics from a meaning-making perspective. We think that one of the most important beliefs to foster is the belief that mathematics involves a web of interconnected concepts and procedures. Related to this belief are several beliefs about the relationship between concepts and procedures: that knowledge of concepts is more powerful and generative than knowledge of procedures and that one can know procedures without understanding the underlying concepts. If prospective teachers begin to appreciate the importance of concepts in developing mathematical understanding, they might approach their course work by trying to develop conceptual understanding rather than by memorizing a technique for a test (see Figure 1 for a model of this belief system).

The other beliefs that we would like to foster are related to teaching and learning mathematics. We hope that prospective teachers come to believe that children bring to school a

great deal of informal mathematical knowledge that can be the basis of instruction. We would like them to recognize that often the ways children think about mathematics differ from the ways of adults who have been schooled. These beliefs will affect prospective teachers' approaches to their mathematics course work by helping them appreciate that their mathematical knowledge needs to be extensive enough to enable them to look at problems from multiple standpoints. They have to be prepared to see the legitimate emergent mathematics in various approaches as well as the misconceptions or overgeneralizations that may be underlying a child's technique. Before they can develop this kind of mathematical knowledge, prospective teachers must believe that building on children's informal knowledge is a worthwhile endeavor. Ebby (2000) wrote about these beliefs as "a conceptualization of students as active meaning makers rather than passive receivers of knowledge (p. 75)." Finally, we hope that prospective teachers develop the belief that mathematical understanding develops slowly, in other words that children do not always learn what the teacher presents.

How do we nurture this idealized belief system in our prospective teachers? Before describing the IMAP program and the ways it theoretically will reorient prospective teachers to mathematics, I will establish the framework I have adopted to think about the process of belief change that will result in the prospective teachers' becoming reoriented to mathematics. This framework rests on some theories about beliefs: where they come from, the effect they have on individual's interpretations of experiences, their functions in decision making, and the ways separate beliefs combine to create belief systems. After establishing a way of thinking about beliefs, I will consider how beliefs can change within this framework.

*Sources of Beliefs*

Beliefs can be thought of as having one of two primary sources: emotion-packed experiences and cultural transmission (Pajares, 1992). The first source, emotion-packed experience, gives beliefs their “signature” quality. Many people can point to a particular vivid memory from which a particular belief emerged (Nespor, 1987). For example, some prospective teachers give detailed accounts of crying while they struggled to learn their multiplication tables. They relate these experiences to their belief that they are incapable of learning mathematics. These are beliefs that are justified by intense personal experiences that have formed vivid memories. The emotional component of the experience is one feature that differentiates beliefs from other forms of knowledge. In relating this feature to beliefs about teaching, Goodman (1988) suggested that beliefs about teaching were derived from guiding images based on both positive and negative experiences that teachers had as children.

The second source of beliefs, cultural transmission, creates beliefs that may be held at a subconscious level. These are beliefs that individuals develop as a result of living in their cultures, their families, and their schools. These beliefs can be thought of as the learning that results from the "hidden curriculum" of our everyday life and can take the form of assumptions and stereotypes. Because most of their mathematics work in school has involved memorizing procedures, some prospective teachers assume that mathematics always involves memorization, even though they have never heard such a statement. People are often unaware of the culturally transmitted beliefs they hold, taking them for granted because they have never examined or discussed them. These beliefs are typically not justified in terms of intense personal experience. These implicit beliefs may guide behavior in ways that could be characterized as habits, with individuals doing things in particular ways of which they are hardly cognizant.

*Effects of Beliefs*

Beliefs have a filtering effect on new experiences that the individual encounters (Pajares, 1992). This filtering effect can make beliefs quite durable; the effect is evident when prospective teachers do not interpret experiences or information in their courses in the ways that their

instructors intended (Simon, Tzur, Heinz, Kinzel, & Smith, 2000). For example, one colleague of mine had her methods students work with kindergartners during the second week of school. She designed an activity centered on story problems. Her intention was for the prospective teachers to realize that young children come to school with a great deal of informal knowledge. After this field experience, the prospective teachers returned to class impressed with how much the teacher had taught the children in the first week of school (personal communication, L. Clement, Jan. 2001). Their belief led them to interpret the experience as evidence of teaching rather than of the children's informal knowledge. It is this powerful filtering effect of beliefs that makes them play such an important role in learning.

Beliefs serve an important cognitive function at the level of choosing problems and tasks on which to focus. Nespor (1987) discussed this function in terms of the messy domains in which teachers have to make decisions. Even before they develop a strategy for dealing with a problem, teachers have to decide on which problems of practice they are going to focus. Their beliefs about schools, teaching, and children orient them to focus on particular problems rather than others.

### *Belief Systems*

Beliefs, whatever their source, are related to one another, forming belief systems in which related beliefs are connected to one another (Rokeach, 1968). The more connections a particular belief has, the more central it is in the system. Some clusters of beliefs exist with no connection to other clusters in the system. For example, some prospective teachers believe that children should have opportunities to be creative, and this belief might be connected to other beliefs about art and writing. This belief may come from their own creative childhood experiences in these domains. The belief about the importance of creativity may not be connected to beliefs about mathematics, because the prospective teachers have never had creative experiences in mathematics and assume that having such experiences is impossible. Their beliefs about mathematics are separate from their beliefs about the importance of creativity for a child's development.

Green (1971) pointed out that belief clusters may be held in isolation such that they are not connected to other belief clusters. He wrote, “We tend to order our beliefs in little clusters encrusted about, as it were, with a protective shield that prevents any cross fertilization among them or any confrontation between them” (p. 47). When these isolated beliefs are activated by the same situation, the believer can become unsettled by the apparent inconsistency in her beliefs. For example, a teacher might believe that having children figure things out for themselves is important. She might also believe that she needs to prepare her students to do well on the standardized tests that are the currency of academic success in our culture. She knows that one key to success on these tests is quick calculation with the most efficient algorithms available. These two beliefs can lead to very different forms of instruction, leaving the teacher feeling unsettled when she chooses one or the other, because she is not acting in concert with all her beliefs. Green suggested that education involves helping people develop well-connected belief systems to eliminate such inconsistency.

Related to the idea that beliefs exist in connected clusters is the idea that some isolated beliefs are also peripheral beliefs (Rokeach, 1968). These beliefs could be likened to stereotypes in that they are not differentiated. These isolated beliefs are typically beliefs that, being based on assumptions that have been culturally transmitted, have not been examined.

### *Changing Belief Systems*

Growing out of this framework for thinking about beliefs are several avenues for change. First, beliefs can be brought into the open and examined. With this kind of consciousness raising, one could examine inconsistencies so that beliefs might become more coherent and better aligned; in examining their beliefs, individuals consider the decisions they make and the beliefs that drive those decisions. This process helps them to make more principled decisions on the basis of beliefs they believe are important, rather than acting on the basis of the habits of unexamined beliefs. Consciousness raising in the form of reflective practice is at the heart of many teacher education programs. Fenstermacher (1979) pointed out that the role of teacher

education programs should be to support teachers in bringing tacit beliefs into the open so that these beliefs can be transformed into objectively reasonable beliefs.

Another way that belief systems can change is for connections to be made among beliefs; for example, as discussed earlier, one's beliefs about mathematics and beliefs about children's creativity might be connected. In connecting previously unconnected beliefs, one will activate new beliefs in situations in which they might not previously have been activated. Individuals will come to see new possibilities not recognized before in a given situation.

A more dramatic way that a belief system might change is for a new belief to develop. This new belief would be connected to existing belief clusters and would be an elaboration of the existing system. For example, the student who believes that she cannot learn mathematics because she struggled with multiplication tables might have an experience solving a difficult problem on her own. This vivid and emotionally packed experience might lead her to believe that she can solve some mathematics problems; the experience would be connected to her existing beliefs about herself and mathematics. Note that I am not suggesting that her original belief about herself and mathematics would cease to exist. Nothing could erase the vivid memory from which it came, and so it would remain in her belief system. This new belief that she can do some mathematics would become connected to her previous belief about herself and mathematics, possibly enabling her to cautiously try problems she might have completely avoided in the past.

The most dramatic belief change is the reversal of existing beliefs. For example, the revolutionary change in religion and science from people's believing that the Earth was at the center of the universe to their believing that the sun was at the center of the universe was this kind of belief reversal. This kind of conversion is rare, as Kuhn (1970) discussed in the context of the beliefs held by the scientific community; he noted that in a paradigm shift, one way of thinking gets replaced or subsumed by a new way of thinking.

### *Summary of Belief System Theory*

In summary, some beliefs grow out of emotionally charged experiences that leave behind vivid images. Beliefs can also result from the subtle effects of cultural transmission. Beliefs help

individuals make judgments and choose the tasks to which they will direct their efforts. In serving this filtering role, they also affect people's interpretations of new experiences.

Beliefs are connected to one another, forming clusters. These clusters can change when new connections are made among beliefs and when beliefs become more refined. These changes can result when one reflects on beliefs and considers decisions made and actions taken. Changes can also arise from an emotion-packed experience unlike any the individual has had before. This experience creates a vivid, memory-based belief, and the new belief becomes integrated into the person's existing belief system. Finally, when a core belief is reversed, one's whole system can change radically if all the beliefs connected to this belief have to accommodate this reversal.

#### *Belief System Change in Preservice Teachers*

Starting from this framework for thinking about beliefs and how they may change, I will now consider teacher education and the kind of changes one might be able to engender in prospective teachers. Often teacher educators aim for the most radical form of belief change: conversion or paradigm shift. They try to cultivate a reversal of beliefs and are left having failed not only to convert their students to new beliefs about teaching and children but also to promote their learning about teaching. These disappointments have been well documented, leaving Wideen, Mayer-Smith, and Moon, (1998) to suggest that teacher educators might attempt to build on prospective teachers' existing beliefs rather than tear them down. In IMAP, we share this goal of building on prospective teachers' beliefs.

To build on prospective teachers' beliefs, one must recognize that their beliefs about mathematics reside within a larger system of beliefs about teaching. Weinstein (1990) found that prospective teachers place strong emphasis on affective and interpersonal issues because they believe that the most important aspects of a teacher's work are connecting with children, providing them with safe environments in which to learn, and giving them positive attention. Their belief in the importance of teacher as nurturer leads prospective teachers to discount the importance of subject-matter knowledge. Beliefs about the importance of relationship building

endure into the first years of teaching when new teachers often expend a great deal of energy trying to find ways to develop positive relationships with children (Hollingsworth, 1992).

Goldstein and Lake (2000) examined this caring orientation of prospective teachers and found that the beliefs about the importance of caring for children grew out of vivid childhood memories and cultural transmission. They cited the many cultural images of good teachers as being kind and friendly and of bad teachers as mean and hard-hearted. They suggested that these cultural images led prospective teachers to hold stereotypic beliefs, that is, beliefs that were undifferentiated and disconnected from other beliefs about teaching. They characterized these beliefs as partial, underdeveloped, and oversimplified.

Another belief that many prospective teachers hold is that teaching involves presenting information. After having watched teachers provide explanations, most recently at the university, they assume that explaining is a fairly straightforward enterprise (Feiman-Nemser, McDiarmid, Melnick, & Parker, 1988). Simply stated, prospective teachers believe that teachers should be nice and should present instruction clearly.

If one rejects the premise that we teacher educators can convert prospective teachers to whole new ways of thinking about teaching, then these beliefs about teaching as caring and teaching as explaining are the foundations on which we have to build. We must assume that prospective teachers will continue to hold these beliefs while their belief systems change and develop. These beliefs may become connected to new beliefs or become connected to old beliefs in new ways. All indications are that these beliefs will endure while prospective teachers engage in their course work and student teaching. I suggest that we can take advantage of these beliefs as a starting point in our work with students.

In the following case study, I will consider an intervention program designed to catalyze changes in prospective teachers' systems of beliefs about mathematics and teaching. I will consider the program elements that served to reorient the participant to mathematics and teaching. I will then return to the types of belief change outlined earlier to consider which kinds of change occurred for this student. I intend to show that building on prospective teachers'

beliefs about teaching is a viable enterprise; in particular, I plan to show that prospective teachers' beliefs about the importance of caring can serve as the foundation for reorienting prospective teachers to mathematics.

#### CONTEXT, METHODS AND GUIDING QUESTIONS

##### *Description of Intervention*

The intervention was an effort to blend subject-matter learning with learning about teaching early in prospective teachers' time at the university. The hypothesis upon which the intervention was based is that undergraduates who explore mathematical problem solving with children will be reoriented to mathematics so that they will engage in their university mathematics course work from a meaning-making perspective.

In the intervention, called the Mathematical Early Field Experience (MEFE), prospective teachers who were taking their first mathematics course were placed in an elementary school setting where they worked with individual children eight times; activities with the children centered around mathematical problem solving. The MEFE was considered a course and met for 2 hours, once a week. Fifteen students were recruited for the course before the semester began and were compensated for their participation. Typically the prospective teachers met with their instructor for a half hour to review the problems they would be doing and to anticipate issues that might arise. They then worked with children for 45 minutes and returned to the group of prospective teachers to discuss and reflect on the experience.

The prospective teachers were given specific tasks and activities designed to elicit children's thinking and to make the children's mathematical understanding apparent. The emphasis was on problem solving rather than symbol manipulation. The prospective teachers had opportunities to work with various manipulatives and hand-held computers to support the children in making sense of the ideas.

Each prospective teacher worked with a partner; one in each pair led the problem-solving session with the child, and the other took notes. The partners were encouraged to help each other, and during the session with the child, they often exchanged ideas about which problem to do

next, what question to ask, and so on. The partners could reflect on the experience afterward and consider issues that arose in the interview.

During the first weeks of the course, the prospective teachers worked with primary-grades children. The goal in this phase of the MEFÉ was to acquaint the prospective teachers with children's problem-solving abilities. This part of the intervention was designed to influence the prospective teachers' beliefs about children's informal knowledge and their tendencies to act out story problems. During these first weeks, the prospective teachers worked with a different child each week.

During the last 4 weeks of the course, each pair of prospective teachers worked with one fifth-grade child on fraction concepts. This part of the intervention was designed to show that a concrete approach to this difficult concept can help children develop understanding. We, the IMAP staff, expected that many of the children would have difficulties, particularly in making sense of the symbolic aspects. We hoped that the prospective teachers would come to see that real-world contexts and careful use of drawings and manipulatives would help them in teaching the children.

I elected to focus on an individual prospective teacher to consider the following questions:

- Did the student develop the beliefs that we hoped she would?
- How did the student's existing beliefs support her belief change?
- What aspects of the experience contributed to the change? What is the power of prospective teachers' working with individual children in problem-solving environments?
- Which of the four previously identified kinds of belief-system change, from consciousness raising to paradigm shift, were applicable to this student?

#### *Participant Selection*

The IMAP researchers used purposeful sampling (Yin, 1994) to select five participants for case studies. We wanted to follow students who had the most to gain from the MEFÉ because their beliefs were far away from the beliefs that we had identified as important. We also wanted

to follow students who differed in terms of both their comfort with mathematics and their demographic characteristics. We identified several students who had the most to gain from the IMAP intervention and from that group chose two who reported being anxious about mathematics and displayed minimal mathematics understanding and two who reported comfort with mathematics and displayed competence with standard algorithms. We also chose one student who seemed to be between these two extremes.

In this analysis, I will limit the focus to one student to consider ways in which the MEFE experience catalyzed changes in her beliefs. I selected a student who did not fit the stereotype that mathematics educators tend to hold about prospective teachers. In my own teaching of methods courses, I had been challenged by students who had been successful with mathematics as children and were procedurally competent. There was little in the literature to guide my work with these students because the research literature focused on students who were not successful with elementary school mathematics and did not like it. I chose to focus on a student who had mastered the procedures of elementary mathematics so that I could not only understand the MEFE and its potential as a catalyst for change but could also better understand procedurally competent prospective teachers.

#### *Data Sources and Analysis*

The student was concurrently enrolled in the first mathematics-for-elementary-teaching-candidates' class and the MEFE, and data were collected in both contexts. Data sources included field notes, belief surveys, interviews, and the prospective teachers' written work. Data were collected by a team of five researchers including, the author, two senior researchers, a post-doctoral student and a staff member. Each student in the MEFE completed a computerized belief survey before and after the semester. The case-study participants were interviewed five times during the semester: once as a follow-up to the initial administration of the belief instrument, once to get their impressions of the mathematics course, twice to discuss their MEFE experiences, and once at the end of the semester to capture their final thoughts.

During the mathematics class, field notes were collected by three observers. One observer kept track of the flow of events in the class, and two observers focused on individuals. We attempted to document the level of participation of the students as well as the material that was covered. Copies of homework and tests were also used to document the learning of the participants.

Field notes were taken during the MEFÉ class discussion and during prospective teachers' work with children. Each prospective teacher in the MEFÉ was videotaped once while she or he led the problem-solving sessions with a child. These data were used to determine whether the prospective teachers focused on concepts or procedures in their work with the children. They were also used to determine the degree to which the prospective teachers followed the script of the activities they were given. After each problem session, the prospective teachers wrote "quick-writes" in which they shared their initial impressions; they wrote longer reflections as homework. Finally, informal conversations between researchers and prospective teachers formed another source of data.

The case study was primarily instrumental (Stake, 1995) as the intention was to understand the MEFÉ and its effects rather than to understand all of the beliefs of the case study participants. These data were coded using two sets of codes: One set related to the ideal beliefs that the intervention was designed to nurture; the other involved those issues that the prospective teacher raised when she interpreted her experience. Memos were produced during the semester to capture the prospective teachers' growth. While coding progressed and themes emerged, data were revisited when the researchers looked for confirming and disconfirming evidence of hypotheses. The research team consulted during data collection to confirm impressions of the participants and their participation in the mathematics class and the MEFÉ.

#### *Description of Case-Study Student*

Donna was a transfer student who had spent her first two years of college at a community college. She participated in the IMAP project during her first semester at the university. She reported that she had enjoyed mathematics as a child and had been successful in it. She was an

active class participant, responding to questions from the instructors, asking questions of her own, and volunteering her mathematical thinking when appropriate. She reported that she felt comfortable in the class and never hesitated to participate. She particularly appreciated the personal interest that the instructors took in the students.

*Beliefs at the Start of the Semester*

At the start of the semester, Donna had a few of the beliefs that we were hoping to foster. She had some faith in children's abilities to derive answers to problems on their own. On the initial belief instrument she responded that first graders would be able to solve a multiplication story problem by building the groups with blocks and counting the total. She showed interest in children's approaches and could describe the details of what they could do. For example, after completing homework for which she watched videotape of children solving story problems, Donna noted that the child had built numbers using tens and ones and had counted his result by twos. This level of detail was unusual inasmuch as other students tended to talk only about whether children's answers were correct.

Donna believed that the most important part of mathematics was learning standard procedures. She thought that standard algorithms were the best way to solve problems and assumed that children who performed them had good understanding. She was not interested in alternative approaches to the standard algorithm, dismissing such approaches as unworthy of her attention. Her comments about alternative approaches included, "It just seems difficult and way too beyond what is really necessary."

Two beliefs emerged from the data that were of particular importance to Donna's case. A few of Donna's statements in her first interview indicated that she held the "teaching as telling" orientation common to most prospective teachers (McDiarmid, Ball and Anderson, 1989). When asked what she thought she might learn from her mathematics course, Donna responded:

Actually, I feel pretty comfortable being able to teach mathematics to children already. Maybe just different ways than I'm used to so that kids if they don't get it one way, I can tell them a different way, or show them. (initial interview)

When, in the same interview, she was asked which of several addition strategies she would like for children to share with their classmates, Donna, assuming that the teacher would show the strategies; stated, "Also, when showing kids that way, that's the easiest to show." She was asked several questions related to these addition strategies, and, throughout, she continued to assume that she as the teacher would be showing the strategies, even though the emphasis in the question was on the strategies being shared by the children who generated them. Even when, at one point, she was reminded that she would not necessarily be teaching these strategies, she continued to assume that she would. Although we did not set out to directly assess a belief about teaching as telling, we infer from the way Donna responded to questions that she, like many prospective teachers, held this belief.

Although we did not gather data relevant to this belief at the start of the semester, we assume that Donna shared the belief that teaching is nurturing, a belief that other researchers have found to be common among preservice elementary school teachers (Weinstein, 1990, Goldstein & Lake, 2000). She told us that she intended to be a kindergarten teacher because she loved little children so much. She had also worked extensively with children during and after high school. She made no statements that caused us to question our assumption that Donna believed in the importance of teachers' being kind and developing positive relationships with their students.

To summarize, Donna believed that children could come up with novel solution strategies to mathematics problems and that children had mathematics experiences before coming to school. She did not believe that mathematics was an interconnected web of concepts and procedures, instead she thought that the efficient execution of standard algorithms was the focal point of mathematics. She seemed to have the beliefs that teaching involves explaining things to children and being nice to them.

*Significant Experiences in the MEFE*

During the MEFE, Donna's four sessions with her fifth grade student, Belinda, left the greatest impression on her. The focus of this work was to explore, using the pattern blocks, relative sizes of fractions and different names for fractions greater than one. Donna also asked Belinda to solve equal-sharing problems that resulted in mixed-number answers and to explore mixed-number representations on hand-held computers. The tasks were designed to build conceptual understanding and to deemphasize the symbolic work that often leads children to misconceptions (Mack, 1995).

In their first session, an assessment with Belinda, Donna and her partner found that Belinda was relatively unfamiliar with fractions. The second session was a high point for all involved. Belinda seemed to enjoy working with the pattern blocks and was able to build representations for a variety of fractional quantities. Because she was so successful, Donna and her partner had her work a few problems involving number symbols, converting improper fractions to mixed numbers. She successfully converted five mixed numbers with some prompting from Donna and her partner. Donna was enthusiastic about the experience:

Our interview with Belinda went surprisingly well. I was so stoked as we taught her how to do mixed numbers and improper fractions and she picked up on it and was able to write her own. She even was able to do  $23/12$  into  $1\ 11/12$  and  $10/4$  into  $2\ 2/4$ . I was amazed.  
(Quick-write response immediately after the interview with Belinda)

Belinda's knowledge grew tremendously.... Belinda flew through problems.... Belinda whizzed through problems. (Formal interview write-up)

The enthusiasm surrounding this episode was due in part to the child's attitude. Belinda was relaxed and animated while she worked with the blocks. She was able to respond to questions and generate answers on her own, without much help. From Donna's perspective, Belinda was working through problems independently. The only point at which Belinda expressed doubt was when the students gave her problems she could not solve with blocks. By

the end of the session, Belinda was able to successfully convert improper fractions to mixed numbers without the aid of pattern blocks. Donna was excited because she believed that she had taught Belinda something.

The follow-up session was a let down for Donna. Instead of starting with equal-sharing problems (the MEFÉ plan for the day), Donna and her partner began with symbol-based conversion problems. Belinda was unable to symbolically convert  $7/6$ ,  $9/6$ , or  $13/12$  into mixed numbers without significant help. Belinda was successful at solving problems situated in story contexts about children sharing cakes and cookies. She worked each sharing problem in several different ways, using drawings.

In her writing and conversations in class, Donna focused on Belinda's struggles with the number symbols. Her comments included:

Belinda had forgotten much of what was taught her from the last time. ... She was more confused than anything else today. (Quick-write response)

That was the hardest interview yet. It's hard when they don't get things. (Conversation)

She was never really sure of herself today. She more played off N's [Donna's partner] and my facial expressions, and if we made comments like "You're doing great," she would keep going, but if we made no comments or no smile or anything, she would erase her work and start over. I felt as though she didn't have any self-confidence. (Formal writing)

Donna's observations were consistent with my interpretations of the session, particularly her observation about Belinda's reading facial expressions. Donna was clearly discouraged that the previous teaching episode had not resulted in Belinda's remembering how to convert improper fractions to mixed numerals. Donna's focus on Belinda's struggle rather than on Belinda's success might be due to Donna's personal investment in Belinda's learning. Donna was excited by the teaching she thought she had done and became deflated when the learning turned out to be temporary. She gave the review problems because she had expected them to be easy for Belinda and was disappointed when they turned out to be quite difficult.

*Growth Toward Ideal Beliefs*

Donna's comments, at the end of the semester, about what she would tell other prospective teachers show that this episode had a great effect on her: "Well, like I said before, not to expect, that a child knows what you've taught 'em, because just because you've taught 'em doesn't mean that they understand it" (End-of-semester interview). We inferred from this comment that Donna originally did expect that Belinda would know what Donna thought she had taught her. After working with the child a second time, Donna realized that results of such work are not as predictable as she had anticipated.

Donna's reaction to the experience indicated that she was beginning to develop the belief that mathematical understanding develops slowly. At the start of the semester, she had shared with many of her classmates the assumption that children learn what they are taught, an assumption derived from the traditional mathematics curriculum delivered in most schools. Her experience in working with Belinda challenged this assumption and caused her to reexamine this belief.

*Revision of Beliefs About Teaching*

Donna's comment advising other prospective teachers not to expect that children will understand what has been taught indicated an elaboration of her beliefs about teaching in general. She articulated awareness that presenting information does not ensure that children will learn. Later in the interview Donna commented further:

You have to make learning fun for children and relate it to the real world, and not drill it into their heads, but just give them their own (pause). . . . When children learn, they need their own space and time to learn on their own. Let them have a chance first, and then see what they need help with. (End-of-semester interview)

This comment illustrated an expanded view of teaching when Donna talked about assessing students' understanding before showing them what to do. She also mentioned giving students time to learn on their own. Her teaching experience supported her in focusing on the learner

more than on the teacher. Her beliefs about teaching became more elaborate than the limited view of teaching-as-telling that was apparent at the beginning of the semester.

Donna's beliefs about the affective components of teaching seem to have changed as well. In reacting to her MEFÉ experience, she focused on Belinda's lack of confidence. Donna repeatedly talked and wrote about Belinda's dependence on her for feedback. For example, she wrote

It became all the more clear to us just how much Belinda relies on our comments and tone of voice. Belinda, we feel, doesn't really trust herself enough; she changes or keeps her original answer based on our comments and/or questions. (Formal interview write-up)

Her comments indicate that Donna, worrying that her teaching practices had interfered with the child's confidence, felt some dissonance. Other students in the MEFÉ shared similar concerns that they raised in group discussions of the children's work. The researchers also noted the children's dependence when they observed the interviews. The dependence was particularly acute when the prospective teachers attempted to teach the children symbolic procedures. Many students in the class shared the goal of having the children be autonomous learners and were frustrated that their attempts at teaching were not fostering the autonomy they had hoped to promote.

This concern was evident when Donna responded to the question "What advice would you have for other students about to start the MEFÉ?"

I say that it is good to give positive reinforcement, *but not too much, because a lot of times our girl grew dependent on what we would say* (italics added), and then if we didn't say, "Oh, great job, Belinda," then she would think she was doing it wrong. She kind of wasn't so sure of herself since we... well, I, a lot of times,... gave her a lot of positive reinforcement, and then it doesn't necessarily mean that she was sure. Sometimes even she would just be guessing, and I'd say, "Good job," and I didn't know she was guessing. Ya know, stuff like that. (End-of-semester interview)

Although Donna still advocated giving students positive reinforcement, she qualified this advice. Donna had given a great deal of indiscriminate praise in her initial interviews, and she

realized that she was not always listening closely to what the child was saying. After Donna spoke about her realization, I reviewed the videotape of her interview with one of the primary children. In that interview, she had complimented the child once if he got the problem wrong and up to three times when he was correct—in these cases, she often complimented him while he was solving the problem, for example, “That was a good way to think . . . very good . . . excellent.” In the third session with Belinda, Donna began to recognize Belinda’s dependence on this praise and commented on it many times after that. After she had this realization, her compliments diminished in both number and emphasis.

Several times Donna expressed concern that Belinda did not have much self-confidence. Such comments indicate that Donna was beginning to wonder about the wisdom of providing the level of positive reinforcement she had provided. She still felt that providing praise was important, but she seemed to recognize that it might not lead the student to develop confidence. Her experience with Belinda cast some doubt on what was before a taken-for-granted assumption that teachers should be encouraging.

Donna’s focus on Belinda’s dependence points to the kind of vivid impression from which beliefs grow. The structure of Donna’s belief system began to change when she experienced the complexity of promoting autonomy. She developed the belief that children should be confident in their abilities to do mathematics and recognized that praise alone would not support the confidence that she hoped to promote. She began to see that the caring and nurturing work of teaching involves more than being supportive and, specifically, that she would need to be more careful in her use of praise. Her stereotyped belief about the importance of being nice became more elaborated when she noticed how dependent on her feedback the child had become. I hypothesize that by reflecting on future experiences, Donna would notice the kind of feedback that empowers rather than creates dependency, further elaborating her belief.

To summarize, Donna was affected by the ups and downs of her work with Belinda. She was enthusiastic about the teaching that she thought she had done and then deflated when her teaching turned out to be ineffective. She came to believe that children do not always learn

what's presented to them, that mathematical understanding develops slowly. She also began to realize that the emotional work of teaching is more complicated than simply being encouraging. While her work with Bleinda had an impact on Donna, it did not catalyze all of the belief change that IMAP staff had hypothesized. I will now consider the beliefs that did not develop as a result of this experience.

### *Beliefs That Did Not Change*

Among the beliefs that we had hoped to nurture were beliefs about the relationship between concepts and procedures, particularly beliefs about the importance of focusing on concepts before teaching procedures, the generative power of concepts, and the potential for procedures to be executed automatically without one's understanding the related concepts. I found no evidence that these beliefs were part of Donna's belief system. This is particularly striking given that Donna was participating in a math course and the MEFE both of which were directed toward developing a conceptual orientation to mathematics. Her beliefs about concepts and procedures were limited to the belief that the standard algorithm is the best way to solve problems. This stance was evident at the start of the semester when Donna was asked to compare two subtraction approaches, the standard algorithm, which was called Lexi's approach, and the following sequential approach, which was called Ariana's approach:

$$\begin{array}{r} \text{Ariana:} \\ 635 - 400 = 235 \\ 235 - 30 = 205 \\ 205 - 50 = 155 \\ 155 - \underline{2} = 153 \\ \quad 482 \end{array}$$

Ariana says, "First I subtracted 400 and got 235. Then I subtracted 30 and got 205, and I subtracted 50 more and got 155. I needed to subtract 2 more and ended up with 153."

In comparing the two approaches, Donna observed

Lexi's approach is very straightforward. Ariana's, on the other hand, is extremely confusing. It seems as though she doesn't possess basic math skills. ... Her approach

makes no sense at all. ... I think she made it a lot more difficult than it really needs to be.  
(Start-of-semester belief survey)

Donna made similar comments when she looked at other collections of approaches, always preferring the standard algorithm and not looking very closely at alternative techniques. Her comment that Ariana's approach was "a lot more difficult than it really needs to be" was repeated often when she examined alternate approaches. Her perception seemed to be that school mathematics entailed students' producing answers to computations in the shortest possible amount of time. This view is consistent with the kind of teaching that she had undoubtedly experienced as a child.

When Donna was asked to compare the same two subtraction approaches on the postsurvey, she continued to assume that children using the standard algorithm had better understanding than children using Ariana's approach. She wrote:

Lexi shows the greatest understanding because she seems to know more about grouping.... Both show the understanding of different mathematical concepts ... all people learn differently and some approaches are easier for certain people than others.

This response indicates that Donna was now more willing to accept Ariana's approach as a viable alternative to Lexi's. However, she considered it as a back-up for the standard algorithm. She did not see Ariana's approach as involving more conceptual understanding, as did some of her classmates, not recognizing that the process of Ariana's would be easier to follow than the renaming involved in the standard algorithm, Donna assumed that children would be more successful using Lexi's approach.

Donna's faith in procedures was also evident in her mathematics course work. She was fluent in the arithmetic procedures for operating on whole numbers and fractions. She attempted to solve problems using drawings rather than algorithms but would readily give up when she had difficulty. Her final examination revealed that she had not mastered the ability to operate on

drawings rather than number symbols. This result indicates that she did not embrace the belief that concepts are at least as important as procedures.

Donna's preference for symbolic manipulation was also evident in the MEFÉ when she focused on converting improper fractions to mixed numerals in symbolic form rather than focusing on the contextual problems that she had been encouraged to use with Belinda. In Fraction Session 3, Donna chose not to follow the MEFÉ directions for the day and instead chose to begin working on the symbolic manipulation that she and her partner had addressed with Belinda during the previous session. Donna did not believe that developing the concepts of fractions first was important; instead she focused on symbol manipulation.

The persistence of Donna's beliefs about the importance of symbol manipulation over conceptual understanding may be due to its cultural roots. Most curricula focus on the standard algorithms. Donna (and many of her peers) believed that content in these curricula or the textbook must be the best type to teach. She had faith that the curriculum her teachers had used had been organized around procedures that were the easiest to understand. Because she had been successful in learning the algorithms, she had no reason to question the curriculum and its emphasis on procedures.

That someone who had success with symbol manipulation would believe that symbolic manipulation was the center of mathematics is not surprising. Donna reported that she loved mathematics because she could "crank out" answers. Her work in the MEFÉ did alter this belief at least a small amount. In the middle of the semester, she observed that she had never been curious about why things worked in mathematics but that after working with a child, she realized the importance of teachers' understanding "why" when they teach the material. We viewed this comment as minor evidence that Donna was beginning to believe that mathematics is a web of interrelated concepts and procedures. A great deal more evidence and reflection will be required for Donna to elaborate this belief.

*Summary of Belief Change*

Donna's belief system changed in two important ways, but much of the system remained intact. She developed the belief that in mathematics, children often need a variety of experiences with a topic to learn that topic. She revised her expectation that if something is taught well, then students will learn it. She expressed this view in the context of discussing her attempts to teach Belinda how to convert improper fractions to mixed numbers. Donna connected a belief about the importance of promoting confidence to her beliefs about teaching mathematics. She developed a keen sensitivity to her student's confidence level.

She did not change in all the ways we had anticipated that students might change. She began to think that concepts were important insofar as they are necessary to explain the workings of procedures. She did not adopt the perspective that concepts themselves merit attention.

## CATALYSTS FOR BELIEF-SYSTEM CHANGE

I have reviewed Donna's experiences and her interpretations of those experiences and have hypothesized about changes in her belief system relative to the system that we in IMAP consider optimal. In this section I will consider the aspects of the MEFÉ that promoted the moderate changes that Donna experienced.

*Focus on Mathematics Learning Rather Than on Classroom Management*

The fact that Donna worked with an individual child was critical to the success of the MEFÉ as a catalyst for change. Because she was working one-on-one with the child, Donna did not face the cognitive overload that can accompany teaching. When prospective teachers are in student-teaching situations, they must attend to all the issues of class management *and* content, and their cognitive capacity gets overwhelmed by all of the stimuli they are trying to assimilate (Hollingsworth, 1989). Through her work with an individual child, Donna had clear evidence that the child was struggling and that her own teaching resources were not developed enough to help the child. Donna could concentrate her thinking on this issue because she was not distracted by the host of management issues that typically concern student teachers.

Also, Belinda's struggles were clear to Donna because she could focus on one child's learning rather than on the learning of several in the class. Donna had given the best explanations of which she was capable, and she knew that the child had heard the explanations. She could not attribute the failure to the child's behavior, attention span, or attendance. Nor did Donna have the option to turn to a different child to get the answers she sought; no other children could "bail out" Belinda or Donna. Both had to face the fact that this was difficult material to teach and learn.

### *High Cognitive Demand*

Although in the MEFÉ we strip away some of the extraneous factors that occupy teachers' minds, Donna had to think about several things while she worked with Belinda. She experienced what some call "knowledge in use" (eg., Ball, 2000), that is, the knowledge that teachers must use in the entangled domain that is teaching. She had to consider the mathematical concept at hand. She had to attend to what the child was doing and consider what understanding the child had. She had to decide what question to ask or what problem to provide to extend the child's understanding. She had to decide what representation would help the child better understand the concept. Her cognitive capacity was taxed while she kept track of all these issues.

The emphasis on problem solving in the MEFÉ created another cognitive demand on Donna. She could not resort to the kind of teaching she had probably experienced as a child. She knew that she was expected to give the child opportunities to "figure things out" for herself. This constraint raised for Donna challenges that she had not faced before. She had to do her own problem solving while she tried to help Belinda, but she realized that her mathematical understanding was not deep enough to allow her to supply this kind of help. Donna resorted to symbolic manipulation with Belinda because this was the content she knew best. For Donna, working with Belinda in the domain of pictures and drawings was difficult because she was not comfortable with this content herself. Helping Belinda with traditional textbook exercises would not have had the same cognitive demand for Donna.

*Element of Surprise*

Donna assumed that Belinda would remember the converting-improper-fractions procedure Donna and her partner had taught. She provided the review problems in the third session because she fully expected that Belinda would do them quickly and that they would then move on to other problems. Donna believed that children learn what has been taught them. When Belinda did not retain the procedure, Donna had to resolve this contradiction between her expectation and the outcome. One explanation would be that the teaching had been poor, but Donna had given the best explanation she could give and had seen that Belinda was able to use the procedure several times. Donna then developed another explanation for this unexpected phenomenon: Children do not always learn what has been taught. If the session had proceeded as Donna expected, without any surprises, Donna's existing belief system would not have been challenged.

Several other students in the MEFÉ course had similar experiences of trying to teach something only to find that their child had not learned it. Several students commented that this experience upset them and made them more aware of how difficult these concepts were to learn. These conversations contributed to Donna's reflection on this new belief.

Donna's efforts to teach Belinda to convert improper fractions to mixed numbers could be characterized as a failed teaching experience. Weinstein (1990) suggested that failed teaching experiences were critical in helping prospective teachers to overcome their optimistic bias about their abilities as teachers. She speculated that prospective teachers needed to see that teaching was not as easy as they had believed and that facing the challenge of teaching remedial students would affect their beliefs.

When prospective teachers encounter challenging teaching situations, they begin to realize the importance of subject-matter knowledge. In an interview, Donna commented that she realized that she needed to know more than just the procedure, that she needed to understand the *why* in addition to the *how*. She said that she had always liked mathematics and had never felt the need to know why, but for teaching she needed to know why so that she could better meet the

needs of her students. If the interview in Session 3 had gone smoothly, I do not believe that Donna would have come to this conclusion.

### *Emotionally Charged Experience*

One critical feature of Donna's work in the MEFÉ was the interpersonal component. Throughout the semester Donna proclaimed her love of children and her strong desire to be a teacher. Working with Belinda on fraction concepts provided Donna an opportunity to connect with a child and to develop a relationship. This one-on-one teaching situation was intimate in that Belinda was asked to share her thinking and Donna was committed to listening. Goldstein (1999) wrote about this kind of interaction as involving both an intellectual component and an emotional component, requiring engagement and receptivity on the part of the teacher. This kind of engrossing experience has the emotional charge that I argued earlier engenders beliefs.

Without the personal investment, the experience would not have had the emotional charge that leaves an impression. Donna's preexisting belief in the importance of caring was critical to making the work with Belinda a powerful catalyst. Working one-on-one allowed her to concentrate on the child rather than on management. It allowed her to connect with the child and at the same time to recognize the limits of the child's understanding. The teaching was complicated because she did not have a ready-made script to follow and she had to do some thinking "on her feet", contributing to the intensity and novelty of the experience. The uncertainty of the experience led to surprises. This uncertainty was due in part to the nature of the tasks that Donna presenting to Belinda. All aspects of the MEFÉ contributed to the vivid impression that it left on Donna. It is this kind of impression that I argue is the genesis of new beliefs.

### BUILDING ON EXISTING BELIEF SYSTEMS

The belief change that I have attempted to illustrate focused on the elaboration of beliefs and the formation of new connections among beliefs. In the case of Donna's beliefs about children's having confidence, I argue that her beliefs became connected in new ways. Donna's belief about children's confidence became connected to her beliefs about mathematics. She had

apparently neither considered how constant indiscriminant praise can erode confidence nor recognized confidence as an important component in mathematical success, perhaps taking confidence for granted because she was so comfortable with mathematics herself. When she connected her beliefs about confidence to her beliefs about mathematics, she began to look at her own interactions with Belinda in a new way. When she gains more experiences, these newly connected beliefs may cause further shifts in the ways she thinks about mathematics teaching and learning.

In the case of recognizing that children do not always learn what has been taught, I argue that Donna developed a new belief that became connected to her existing beliefs about teaching. Her original belief about teaching was undifferentiated because of her limited experiences. I speculate that she had not had opportunities to reflect on her beliefs about teaching, leaving them at the subconscious level. When she faced evidence that contradicted her beliefs that teaching involves telling, this belief became more salient to her. To resolve the contradiction, she revised her belief to include a component of finding out what children know before instructing them. Her belief about teaching was elaborated when she added to it the notion that teachers should listen to children to determine at what point to begin instruction.

Her initial beliefs about the importance of caring for children created the potential for these changes to take place. I doubt that Donna would have changed if working with a child had not been part of the experience. Her relationship with the child motivated her to persist in working on some challenging teaching issues that she otherwise would have been unlikely to pursue. Her enduring belief about caring was the belief that stimulated her to take her work seriously and to revise her existing system.

I discussed earlier the folly in trying to create paradigmatic shifts in prospective teachers' beliefs systems. I suggested that building on belief systems was the more prudent course of action and the one we take in our IMAP work with our prospective teachers. By tapping into the prospective teachers' preexisting beliefs about the importance of caring in the act of teaching, we in IMAP were able to catalyze what we hope will be ongoing changes in belief systems both

about mathematics and about teaching. We recognize that the belief change seems rather small. We are reassured by the knowledge that this change has occurred early in the students' teacher preparation program. We expect that Donna and her fellow students will continue to have experiences that will help them to make new connections in their belief systems and to develop new beliefs that they have to integrate into their systems. In my analysis I suggest that individual work with children promote changes in prospective teachers' existing belief systems in a way that less intimate experiences do not.

We believe that her experiences with Belinda will contribute to Donna's motivation to learn mathematics in her subsequent courses. Donna realized that the work of teaching, in general, and the work of teaching mathematics, in particular, were more complicated than she had ever imagined. She recognized that her knowledge of mathematics needed to be deep and secure to enable her to listen to the child and make immediate decisions without having to second guess her own knowledge of the mathematics she and the child were exploring together. She also came to see that the work of caring was more complicated than she had anticipated. She noticed that "being nice" was insufficient to help a child develop the confidence that she began to believe was important in learning mathematics.

Donna did not change in all the ways for which we in IMAP had hoped, leaving us to wonder how we can change the MEFÉ to better address the procedural orientation of many prospective teachers. While Donna continues to consider children's confidence, she may come to see that children develop confidence in their own thinking when they generate their own approaches to solving problems rather than when appropriating an approach their teacher shows them. This may be the connection that catalyzes further change in Donna's beliefs.

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### References

- Ball, D. (1990) Prospective elementary and secondary teachers' understanding of division. *Journal for Research in Mathematics Education*, 21, 132-144.
- Ball, D. (2000). Bridging practices: Intertwining content and pedagogy in teaching and learning to teach. *Journal of Teacher Education*, 51, 241-247.
- Cooney, T. J., Shealy, B. E. & Arvola, B. (1998). Conceptualizing belief structures of preservice secondary mathematics teachers. *Journal for Research in Mathematics Education*, 29(3), 306-333.
- Ebby, C. (2000). Learning to teach mathematics differently: The interaction between coursework and fieldwork for preservice teachers. *Journal of Mathematics Teacher Education*, 3, 69 – 97.
- Feiman-Nemser, S., & Buchmann, M. (1986). The first year of teacher preparation: Transition to pedagogical thinking. *Journal of Curriculum Studies*, 18, 239-256.
- Feiman-Nemser, S., McDiarmid, G. W., Melnick, S., & Parker, M. (1988). *Changing beginning teachers' conceptions: A study of an introductory teacher education course*. East Lansing: National Center for Research on Teacher Education and Department of Teacher Education, Michigan State University.
- Fenstermacher, G. (1979). A philosophical consideration of recent research on teacher education. In L.S. Shulman (Ed.), *Review of research in education* (Vol. 6, pp. 157-185).
- Goldstein, L. (1999). The relational zone: The role of caring relationships in the co-construction of mind. *American Educational Research Journal*, 36, 647–673.

- Goldstein, L., & Lake, V. (2000). Love, love, and more love for children: Exploring prospective teachers' understandings of caring. *Teaching and Teacher Education, 16*, 861-872.
- Goodman, J. (1988). Constructing a practical philosophy of teaching: A study of prospective teachers' professional perspectives. *Teaching and Teacher Education, 4*, 121-137.
- Green, T. F. (1971). *The activities of teaching*. New York: McGraw-Hill.
- Hollingsworth, S. (1989). Prior beliefs and cognitive change in learning to teach. *American Educational Research Journal, 26*, 160-189.
- Hollingsworth, S. (1992). Learning to teach through collaborative conversation: A feminist approach. *American Educational Research Journal, 29*, 373-404.
- Kuhn, T. (1996). *The structure of scientific revolutions*. Chicago, IL: University of Chicago Press.
- Ma, L. (1999). *Knowing and teaching elementary mathematics: Teachers' understanding of fundamental mathematics in China and the United States*. Mahwah, NJ: Erlbaum.
- Mack, N. (1995). Confounding whole-number and fraction concepts when building on informal knowledge. *Journal for Research in Mathematics Education, 26*, 422-443.
- McDiarmid, G. W., Ball, D. L. & Anderson, C. W. (1989). Why staying one chapter ahead doesn't really work: Subject specific pedagogy. In M.C. Reynolds (Ed.), *Knowledge base for the beginning teacher, 193-206*. Oxford: Pergamon Press.
- National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.
- Nespor, J. (1987). The role of beliefs in the practice of teaching. *Journal of Curriculum Studies, 19*, 317-328.
- Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of Educational Research, 62*, 307-332.
- Rokeach, M. (1968). *Beliefs, attitudes, and values; A theory of organization and change*. San Francisco: Jossey-Bass.

- Simon, M., Tzur, R., Heinz, K., Kinzel, M., & Smith, M. S. (2000). Characterizing a perspective underlying the practice of mathematics teachers in transition. *Journal for Research in Mathematics Education, 31*, 579-601.
- Stake, R. (1995). *The art of case study research*. Thousand Oaks, CA: Sage.
- Weinstein, C. S.(1989). Teacher education students' preconceptions of teaching. *Journal of Teacher Education, 4*, 31-40.
- Weinstein, C. S. (1990). Prospective elementary teachers' beliefs about teaching: Implications for teacher education. *Teaching and Teacher Education, 6*, 279-290.
- Wideen, M., Mayer-Smith, J., & Moon, B. (1998). A critical analysis of the research on learning to teach: Making the case for an ecological perspective on inquiry. *Review of Educational Research, 68*(2), 130-178.

Figure Caption

Figure One. Model of prospective teachers' beliefs about mathematics and mathematics learning.

