MATHEMATICS TEACHER DEVELOPMENT:

MAKING SENSE OF PROFESSIONAL DEVELOPMENT

by

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(Under the Direction of Patricia S. Wilson)

ABSTRACT

The purpose of this study was to better understand the process of mathematics teacher development. More specifically, in this study, I examined how mathematics teachers make sense of their professional development experiences in the context of their practice. Goldsmith and Schifter's (1994) model for the development of mathematics teaching provided a research framework from which to view mathematics teacher development. They suggest four components that should be taken into consideration when examining mathematics teacher development: qualitative reorganizations of understanding, orderly progression of stages, transition mechanisms, and motivation and disposition.

The population under study was practicing mathematics teachers engaged in a professional development program who experienced changes in their knowledge and beliefs about mathematics, mathematics teaching, and/or mathematics learning. Data were collected during a week-long summer institute and the subsequent year of teaching. Data sources included observations, interviews, and teacher products (such as open-ended surveys and journals). The data were analyzed to determine how three teachers made sense of their professional development experience (a) from their practice; (b) for their practice; and (c) in their practice.

The research framework guided generalizations of the process of mathematics teacher development. The results showed that teachers construct different understandings from the same experiences, and thus professional development is not entirely about the curriculum. Rather, professional development should be concerned with providing opportunities for teachers' of varying backgrounds to interact with their prior knowledge and beliefs. Also, this study points toward the importance of teachers' initial goals and the dispositions of persistence, courage, and the desire to be different in initiating and sustaining development.

A model of the dynamic relationship between changes in understanding and changes in practice is offered and a critique and modification of the research framework is provided. Because much of how teachers make sense of their professional development experiences is missed when professional development is not thought of in the context of their prior, intended and actual practice, recommendations for those concerned with how mathematics teachers develop include not relying solely on teachers' self reports at the conclusion of a professional development experience.

INDEX WORDS: Educational reform, Mathematics education, Practicing mathematics teachers, Professional development, Teacher development.

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TABLE OF CONTENTS

Page

CHAPTER

CHAPTER 1

BACKGROUND

The mathematics curricula and instruction in the United States have been characterized both nationally and internationally as lacking depth in content coverage, continuity, and active involvement of students during the learning process (National Assessment of Educational Progress [NAEP], 2000; United States Department of Education [USDE], 1996). Motivated by a broad base of empirical research and theoretical literature about how students understand and learn mathematics, reform efforts challenge a lasting tradition of teacher-centered and procedure-oriented mathematics instruction. These efforts have invited teachers to create environments for students that move away from the traditional passive mimicking and memorization of facts and procedures toward reform environments that are alive with mathematical inquiry where students experiment with new ideas, examine their assumptions, ask questions, collect and analyze data, and come to new and deeper understandings (National Council of Teachers of Mathematics [NCTM], 2000; National Research Council [NRC], 1989, 2001).

"Many teachers have embarked on the project of changing their teaching toward that envisioned" (Nelson, 1995, p. 1). But, despite widespread publicity about visions of mathematics education reform, the typical mathematics classroom remains unchanged (NAEP, 2000; USDE, 1996; Weiss, 1995). For example, Thompson's (1992) review of the literature revealed that many teachers remain wedded to instructional strategies based on the view that mathematics is a static body of knowledge to be conveyed by the teacher and received by the learner. Although there is literature that indicates that teachers are recalcitrant (Duffy & Roehler, 1986; Fullan, 1991), there is considerable research that indicates otherwise. For example, Cohen (1990) found that even though Mrs. Oublier, who eagerly embraced the “Math their Way” reform, believed that she had changed her mathematics teaching to be in line with the reform, the understanding she took from the policy was not as intended. Likewise, Wilson and Goldenberg (1998) concluded that even though Mr. Burt, who wanted his own teaching of mathematics to be more conceptually oriented and aligned with students’ thinking, was able to make changes, these changes were limited. These case studies indicate that, even for well-intentioned teachers such as Mrs. Oublier and Mr. Burt, teacher change is a difficult and complex process because it is intricately tied to teachers’ interpretations and their manifestations in the classroom. Because the perspectives that characterize mathematics education reform are a significant departure from those that underlie traditional mathematics instruction, for many teachers, “[t]he kind of transformed practice being called for extends beyond the acquisition and mastery of new teaching techniques and strategies to the reconstitution of fundamental notions of teaching, learning, and the nature of mathematics as a discipline, and to the creation of different opportunities for learning” (Goldsmith & Schifter, 1997). Therefore, “the enactment of these envisioned changes depends heavily on the effectiveness of opportunities for ongoing mathematics teacher development” (Simon & Tzur, 1999, p. 252).

Recognizing that reform visions are radically different from traditional school mathematics, research programs have made important contributions in identifying the effects of changes in teachers’ knowledge of (Ball, 1990; Schifter, 1998; Steinberg, Carpenter, & Fennema, 1994) and beliefs about (Martens, 1992; Olive & Ramsay, 1999; Prawat, 1992) mathematics, mathematics teaching, and mathematics learning on practice. By examining the impact of particular interventions on teachers’ actions, these research programs have provided us with consistent guidelines for planning and implementing professional development experiences that may lead to the development of teachers. Mewborn's (2003) review of the literature discusses several conditions of professional development opportunities that promote positive change. Effective professional development should be long-term, based on a supportive community of learners, and rooted in the knowledge base for teaching. This should include opportunities for teachers' to build their knowledge of mathematics, mathematics learning, and mathematics teaching through: grappling with significant mathematical ideas, focusing on children's mathematical ideas, and trying out what they learn in their own classrooms.

Studies of the ways in which teachers change their practice within a given approach to professional development have laid the groundwork for attempting to understand how teachers develop. Informed by this work, this study goes beyond an emphasis on teacher development as a product of participation in professional development programs by tracking the process of development that occured as mathematics teachers attempted to make sense out of their professional development experience through their practice. According to Goldsmith and Schifter (1997), "at present … we have little general guidance for characterizing the process of developing practice" (p. 48) and Simon (1997) argues that this generation of a research base on the development of teachers is "critical to the success of teacher development" (p. 55). Thus, the limitations of the current research call attention to the need for studies that more fully explicate the process of teacher development. A key step in that process, and the one that this study proposes to address, is understanding the dynamic between changing knowledge, beliefs and practice.

A Pilot Study on Teacher Development

After teaching mathematics courses at the middle school level for five years, I served for one year as a county mathematics coordinator followed by four years of mentoring and instructing prospective and practicing mathematics teachers as part of a graduate assistantship during my doctoral program. In these roles, I was responsible for providing professional development experiences to K-12 teachers. These experiences included teacher education, induction support, staff development, and classroom-based mentoring. Frequently, I experienced teachers' enthusiasm or frustration with their attempts to connect their professional development experiences with their teaching practice. Experiences like these led me to want to know more about how teachers connect their professional development experiences to their classroom.

I planned and conducted a pilot study in which my goal was to to gain insight into the experiences teachers perceived as being significant in facilitating the development of their practice. This was an in-depth interview study of three mathematics teachers involved in a teacher enhancement project. Although the three participants were involved in the same professional development program, they differed by their grade levels (one elementary, one middle school, and one high school), direction of development (problem solving, communication, and technology), and perceived support by students, peers and administration (low, medium, and high). Two themes emerged from the study. First, each participant recognized the importance of the type of learning they experienced. They supported that participating in professional development experiences from a student's perspective made more of an impact on their development than opportunities where they received a package of classroom activities designed by someone else. They claimed that by taking a student role, they not only learned mathematics, but they confronted their beliefs about mathematics, teaching, learning. In other words, they wanted their students to experience mathematics in ways that were consistent with how they had learned themselves. Second, each teacher identified their corresponding classroom and school experiences as significant aspects of their development. Specifically, they identified that interactions with students and colleagues, outside of their professional development work, played an important role in their development.

As I examined my participants' experiences with development, as well as my own, I began to question some of the assumptions that I had made about how teachers develop. In this study, I viewed teacher development as a product of pivotal experiences. Specifically, I thought that identifying experiences that were pivotal to teachers' development, such as opportunities for teachers to take a student role, would aid in understanding teacher development and consequently lead to the design and implementation of better professional development experiences for teachers. But, as I reflected on my participants' stories, my thinking and questioning about teacher development changed from focusing solely on professional development experiences to including their corresponding classroom experiences. From this study, I realized that not only did teachers bring to their professional development experience differing contexts and understandings *from* their practice, but that within any given approach to professional development, teachers construct different meanings *for* their practice. Additionally, these conditions determine what constitute opportunities for reflection and action *in* their practice. Rather than studying teacher development with the sole intent of describing pivotal professional development experiences, I proposed a study that investigated how teachers constructed meaning from their professional development experiences in the context of their practice.

Constructing Teacher Development

Recent reform visions have their roots in constructivist views of knowledge development and research on learning (Piaget, 1970; Skemp, 1987). Constructivism is a theory of meaning-making. The work of Piaget contributed to the epistemological and psychological foundations of constructivism. According to Piaget, knowledge is constructed by individuals through a process of assimilating new information and experiences into current ways of understanding and the resulting modification of their understanding in order to accommodate the new information. "This view of the development of cognitive structures challenges the long established position that learning is a process of receiving facts, skills, and strategies ready made from other sources of knowledge" (Goldsmith & Schifter, 1994, p. 2). Rather, learning is an active process that involves individuals making sense of new information and experiences given what the individual already knows and believes.

Because teacher learning is at the heart of teacher development, (Ball & Rundquist, 1993; Bruner, 1977), development efforts should envision teachers as learners in the same way they ask teachers to view students as learners. "It seems duplicitous to respect children's ways of thinking about mathematics while not doing the same for experienced teachers' ways of thinking about teaching" (Heaton & Lampert, 1993, p. 16). As learners, teachers construct knowledge through the assimilation and accommodation of new ideas with what they already know and believe. Based on this constructivist epistemology and concomitant theory of learning, I offer the following definitions:

1. *Professional development* is any learning experience where teachers meaningfully interact with their knowledge of and beliefs about content, teaching, and learning.. This includes

formal learning experiences such as teacher education and staff development, as well as informal learning experiences such as interactions with students and teachers.

2. *Practice* is what teachers do (actions) and their motivations for what they do (intentions) in their classroom experiences. Teachers' actions and intentions are situated in particular contexts and are heavily influenced by their prior experiences and their existing knowledge of and beliefs about content, teaching, and learning.
3. *Teacher development* is the changes in knowledge of and beliefs about content, teaching, and learning that teachers encounter as they make sense out of new information and experiences through the meaningful interaction of new ideas with what they already know and believe.

Therefore, teachers construct their development through the reflexive relationship between professional development and practice.

Statement of the Problem

Through this study, I sought to understand the process of development teachers encounter as they construct meaning from their professional development experiences in the context of their prior, intended, and actual practice. Specifically, I investigated the following question: How do teachers make sense of their professional development experiences:

a) from their practice?

    In retrospect, what contexts and understandings from their prior experience do teachers perceive as being significant to the changes in knowledge and beliefs they encountered during their professional development experience?

b) for their practice?

    In projection, what meanings (both envisioned and spontaneous) do teachers construct for their intended classroom experience based on the changes in knowledge and beliefs they encountered during their professional development experience?

c) in their practice?

In introspect, what do teachers do (or not do) in their actual classroom experience (both intentional and unintentional) based on the changes in knowledge and beliefs they encountered during their professional development experience?

CHAPTER 2

TEACHER DEVELOPMENT LITERATURE

Although it is well established that there is a connection between knowledge, beliefs, and practice (Thompson, 1992), “examination across studies show little consistency in terms of whether teachers initially change their beliefs, knowledge, or practice, or in how these changes evolve” (Franke, Fennema, & Carpenter, 1997, p. 256). Guskey (1986) asks “[i]n what temporal sequence do these outcomes most frequently occur?” (p. 6). Within the mathematics education literature, there are several theoretical explanations for how knowledge, beliefs, and practice are related. What follows is a discussion of the different perspectives on the nature of the process of teacher development and the components of mathematics teacher development that will guide this study.

Temporal Perspectives

One perspective of the process of teacher development, posited by Guskey (1986), is an evidential view in which change in practice precedes change in knowledge and beliefs. In this view, changes in teachers’ knowledge and beliefs are spurred by tentative changes in their practice that result in positive student learning outcomes. There are several case studies that support this evidential view of development. Take the case of Karen Hill (Prawat, 1992). Although Karen was skeptical about the “Math Their Way” reform, she tentatively adhered to the state-mandated textbook and recommended instructional practices. To Karen’s surprise, her students’ began to use mathematics in unexpected ways. Even though Karen was initially reluctant to experiment with change, her students' positive learning outcomes convinced her that students could learn mathematics in different ways which encouraged her to think more expansively about her teaching practice.

Although there are cases that support an evidential view of the process of teacher development, there are others that support a different order of occurrence of these outcomes. For example, Cooney's (1994) Sue explicitly described changes in her conceptions from participating in a course, prior to any evidence of positive changes in her students' learning. An alternate perspective of the process of teacher development is that change in teachers' knowledge and beliefs precedes change in practice. "This research is based on the assumption that what an individual thinks influences what that individual does. This implies that if we influence teachers' beliefs and knowledge, we influence their practice" (Franke, Fennema, & Carpenter, 1997, p. 256). Many research programs have based their work on this perspective with different foci.

For example, Steinberg, Carpenter, and Fennema (1994) reported a case study of Ms. Statz, an elementary teacher who used the Cognitively Guided Instruction (CGI) approach. CGI has as its goal providing opportunities for teachers to develop the ability to base their instruction on what the child knows by inquiring both into the child's cognitive process and developing a knowledge base of how instruction can be based on those processes. Steinberg, et al. provide evidence that Ms. Statz made changes in her practice, changes which they claim were consequences of her improved knowledge of children's thinking.

In another study, Schifter (1998) explored the relationship between Teresa Bujak's and Beth Keeney's knowledge of mathematics and changes in their practice. Bujak and Keeney participated in a professional development seminar in which they explored mathematics. Schifter provides evidence that both teachers made changes in their practice as a result of their changes in views of the nature of students' mathematical learning encountered from participating in the seminar.

Whereas from an evidential perspective, changes in knowledge and beliefs result when teachers modify their practice and see their students' benefiting, from a cognitive perspective, teacher development is a matter of improving the quality of teachers' knowledge and beliefs. These temporal perspectives of the process of mathematics teacher development have each contributed to our knowledge of the process of teacher development and to professional development efforts.

Iterative Perspectives

As an alternative to temporal perspectives suggested by previous models, Tharp and Gallimore (1988), taking a Vygotskian approach, proposed that within any stage of development, teachers may change either their practice or their knowledge and beliefs. But, neither necessarily precedes the other. This model is supported by Franke, Fennema, and Carpenter's (1997) case studies of 17 CGI teachers in which they found that "there was no single pattern of change" (p. 277). They added that at initial stages of transforming mathematics teaching, change in practice can precede change in knowledge and beliefs, or vice versa. But, at later stages, change in knowledge and beliefs is an integral part of developing practice.

Schifter and her colleagues (Goldsmith & Schifter, 1997; Schifter, & Simon, 1992; Schifter, 1995, 1996) suggest that the process of teacher development involves a continuous interplay between changes in knowledge and beliefs and changes in practice. "These changes in teachers' classroom behaviors serve as a matrix within which changes in beliefs and understanding are embedded" (Goldsmith & Schifter, 1997, p. 27). Taking this Piagetian approach, the process of mathematics teacher development involves changes in practice as well as the knowledge and beliefs that ground and shape practice.

The ultimate aim of research on the process of mathematics teacher development, from an iterative perspective, is an integrated model that encompasses knowledge, beliefs, and practice. In such an integrated model, changes in teachers' knowledge and beliefs and changes in their practice would be both compatible and interdependent. By this I mean that as one develops, it is both integrated into and influences the other. Thus, the goal is to trace how concomitant changes in teachers' knowledge, beliefs, and practice develop over time.

Central to this study was my conceptualization of teacher development, which drove the purpose of this investigation and what I paid attention to in the data. As Cobb (1994) argues, the issue is not which perspective is right, but which is most helpful. In this study, I examined the continuous interplay between knowledge, beliefs, and practice, thus taking an iterative approach to the study of the process of teacher development.

A Teacher Development Research Framework

Drawing on empirical and theoretical literature on cognitive development, Goldsmith and Schifter (1994) suggest the following basic components of developmental models for mathematics teaching: qualitative reorganizations of understanding, orderly progression of change, transition mechanisms, and motivational and dispositional factors. These components should be taken into consideration when examining mathematics teacher development. What follows is a discussion of each of the components that frame this study of the process of mathematics teacher development from an iterative perspective.

Qualitative Reorganizations of Understanding

The first component of mathematics teacher development models is that they describe qualitatively different stages of understanding. "Successive reorganizations are characterized by increasing differentiation of cognitive structures, resulting in the capacity for more complex thought and action" (Goldsmith & Schifter, 1997, p. 21-22). There are a number of researchers of mathematics teacher development who are working on frameworks that describe stages of thought about mathematics, mathematics teaching, and mathematics learning. These frameworks begin with views of mathematics as a static body of facts and procedures to be conveyed by the teacher and passively mimicked and memorized by the learner and move towards mathematics as a dynamic construction by students engaged in activities that build on students' current mathematical understandings. Models of mathematics teacher development should provide descriptions of teachers' knowledge of and beliefs about mathematics, mathematics teaching, and mathematics learning at progressively differentiated stages.

Orderly Progression of Change

Another component of models of mathematics teacher development is that the progression of changes is viewed as orderly, "whereby the challenges to be faced and resolved in the present stage become the base from which the next stage's challenges are created (Goldsmith & Shifter, 1994, p. 7). Because mathematics teaching involves decisions and actions in unique contexts guided by teachers' current understandings, teacher development progresses unpredictably at a local level. Rather, this component of mathematics teacher development models indicates that given a teacher's current understandings, there are aspects of their progression of change that are predictable. Goldsmith and Schifter claim that there are a limited number of alternate pathways that teachers take as they develop. They indicate that if this claim is supported empirically, models of mathematics teacher development should provide descriptions of the progression of these stages.

Transition Mechanisms

A third component of mathematics teacher development models is that they offer mechanisms that account for how transitions proceed from one stage to another. Current theories of development emphasize two types of transition mechanisms: "psychological mechanisms that promote individuals' reorganization of their own knowledge and understanding; and sociocultural mechanisms that provide the context and stimulus for individual change, and that result in the development of new social and intellectual forms themselves" (Goldsmith & Schifter, 1994, p. 8).

Several psychological mechanisms have been proposed for explaining developmental transitions. Piaget (1970) viewed development as a self-regulating process driven by perceived disparities between the individuals current ways of understanding and their environment. He proposed that the mechanisms of assimilation and accommodation move individuals' cognitive structures toward equilibrium-coherence and stability between an individual's current understanding and their environment. Assimilation is a fitting of new ideas and experiences into an existing structure. Accommodation is the resulting restructuring of cognitive structures in response to the perturbation. Thus, when assimilating new ideas and experiences, the individual recognizes only aspects of the experience that fit into their existing cognitive structures. However, in the process of accommodating new ideas and experiences, the individual recognizes aspects of the experience that are inconsistent with their existing cognitive structures. Upon recognition of this perturbation, the perceived disparity between existing understandings and aspects of the environment, an individual enters a state of disequilibrium. Once perturbed, the individual will seek to return to a state of equilibrium.

Several sociocultural mediators have also been proposed for explaining developmental transitions. Within a Vygotskian framework, the sociocultural mechanisms for change lie in the individual's intellectual acquisition of new mediating tools and signs. These tools and signs, which include socially valued relationships and processes of reasoning, help to organize and shape experiences and interpretations of their world. Another mechanism is the social context in which development occurs. In other words, teacher development is affected by the images they have of teaching. A final mediator may be found in the interactions teachers have with students and colleagues. According to Bauersfeld (1988), social interactions progress spirally. As individuals interact, their actions are both the result of prior interaction and the cause for future interactions.

Motivational and Dispositional Factors

Goldsmith and Schifter (1994) argue that a missing component of mathematics teacher development models is the consideration of the ways in which motivational and dispositional factors influence the course of development. These factors include teachers' initial motivations for undertaking development, their sustaining motivations for continuing development, and their influencing dispositions for approaching and resolving developmental issues.

CHAPTER 3

METHODOLOGY

I followed three mathematics teachers from their professional development experiences to their classroom experiences in order to better understand the process of development these teachers encountered as they made sense of new knowledge and beliefs in the context of their practice. Since I wanted to understand how teachers made sense of their experiences, this study employed qualitative data collection and analysis techniques. Using a triangulation of methods, I explicated the teachers' perspective from the researchers' perspective (Simon & Tzur, 1999). My role in this process included: facilitating participants' articulation of their ideas, calling attention to aspects that may have been overlooked by the participant, challenging their perspectives, and introducing alternate explanations.

In designing this study, I defined teacher development as the changes in knowledge and beliefs that teachers encounter as they make sense of their professional development in the context of their practice. So, for this study, I was concerned with how teachers, who have experienced qualitative reorganizations of understanding, make sense out of their changed notions. This process is an evolving set of understandings and practice. Therefore, as I examined the process of development of my participants, I focused on the relationships between their thoughts and actions as they attempted to make sense of, use, and build on their new knowledge and beliefs in the context of their practice. This impacted many of the decisions I made. First, I purposely selected participants from a professional development environment that was likely to provide the opportunity for many teachers to reorganize their understandings. In addition, I selected participants that showed evidence of qualitative reorganizations of understanding. Finally, this component of teacher development informed my data collection. I looked for participants' parallel concepts of mathematics, mathematics teaching, and mathematics learning. The following design is a static representation of this dynamic qualitative inquiry.

Professional Development Selection

The professional development site selected for this study was a summer institute at the University of Georgia. The institute was part of the National Science Foundation supported Center for Proficiency in Teaching Mathematics. The Center is a five-year professional development project that supports the improvement of mathematics teaching and mathematics teacher development. The institute included a five-day workshop component with an ongoing support community for 23 mathematics teachers and 12 mathematics teacher educators. While both groups of participants (the teachers and teacher educators) worked on the teaching and learning of geometry, they had different foci. The teachers, who participated in a demonstration class led by the professor focused on expanding and strengthening their knowledge of geometry, explored open-ended geometric investigations using technology and developed related instructional activities for their classrooms. The teacher educators, as observers of the demonstration class, focused on developing their knowledge of the nature of geometric knowledge needed for teaching.

My rationale for this initial population was the Center's alignment with research-based professional development, thus offering the opportunity for teachers to experience development in their knowledge of and beliefs about mathematics, mathematics teaching, and mathematics learning. Specifically, institute participants: grappled with significant mathematical ideas through open-ended investigations, reflected on the learning of mathematics through surveys and journals, and connected to their corresponding teaching experiences through lesson planning and follow-up activities.

Open-ended Investigations

During the demonstration class, the professor demonstrated open-ended investigations, posed open-ended investigations for the whole class to work on, and encouraged teacher participants to select their own investigations to explore. One problem that was demonstrated was a Geometer's Sketchpad (GSP) construction and animation of a parabola as the locus of points equidistant from the focus and the directrix. In addition to demonstrating investigations of particular topics, the professor posed open-ended investigations for the whole class to explore. One such investigation was to find multiple ways to divide a circle into five equal parts. Finally, teacher participants explored various geometric concepts through their own selected open-ended investigations. The overarching concepts were: points, lines, and planes; shape properties; perimeter and area; volume and surface area; trigonometry; coordinate geometry; transformational geometry; measurement systems; and constructions. Under each content strand, there were multiple open-ended investigations and extensions for teachers to select from based on their interest. Examples included: investigations of the diagonals of quadrilaterals and constructing shapes (such as triangles and squares) of equal area.

Surveys

As part of the research data for the Center, teachers completed Pre- and Post-surveys. The Pre-survey was completed prior to the institute. Most items were open-ended and addressed teacher's prior experiences with geometry, teaching, learning, and technology. The Post-Survey was administered on the last day of the institute. Participants were asked about their experience at the institute and how it impacted their thinking about geometry, teaching, learning, and technology. (See Appendix B and C for Pre- and Post-Surveys) These data were used for this study to select participants and design interview questions.

Journals

During the institute, teachers were asked to respond to four daily journal prompts. Two prompts remained constant each day: ”What are your thoughts and feelings about the mathematics content, open-ended nature of the investigations, and the use of technology for learning?”; and “Other insights and critical learning incidents.” The other two prompts were specific to the days activities (e.g., “What did you learn from the GSP approach to parabolas, hyperbolas, and ellipses?”). Journals were submitted daily to the teacher educators and returned with comments.

Lesson Planning & Follow-up Activities

As part of the course, teachers created lesson plans that integrated geometry and technology for use in their classrooms. Examples of lessons included adapting open-ended investigations, demonstrations, or other course activities to the needs of their particular grade level. In addition, teachers were offered continued support following the institute. Support features included e-mail to a network of peer educators and classroom follow-up.

My role at the Institute

My role in the institute included organizing the sessions and designing survey and journal prompts. Even though the Center had a separate research agenda than mine, by being involved in the planning stages I was able to influence the design of the institute to inform my study. For example, on the Pre-Survey, I was able to ask teachers for the number of years they had been teaching which informed my participant selection. Also, survey and journal prompts such as "what did you learn about mathematics" informed my data collection.

During the institute, I served as a project researcher, primarily observing the teachers for potential participants in my study. I constructed field notes of the teachers' experiences, and documented inferences I made about the changes in understandings of select teachers. These field notes could be used by the institute to capture events, but were focused primarily on informing my participant selection and data collection by providing a common experience to discuss with teachers. I was not involved with the instructional design or implementation.

Participant Selection

A layered approach to participant selection was taken using "purposeful sampling" (Bogden & Bicklin, 1992). The initial population was practicing mathematics teachers attending the institute. Three practicing teachers were selected from this population based on the following participant selection criteria:

1. The participant was a practicing mathematics teacher with at least five years of teaching experience. In this study, I examined how mathematics teachers develop in the context of their prior, intended, and actual practice. This assumes that the participant has prior, intended, and actual teaching experiences. Even though I view teacher development as a life-long process, preservice and induction years are unique stages in teacher development (Brown & Borko, 1992; Feiman-Nemser, Schwille, Carver, & Yusko, 1999). Therefore, I restricted this study to practicing mathematics teachers past the induction years.
2. The participant showed evidence (identified from observations, teacher products, informal conversations, and an initial interview) of changes in their knowledge of and beliefs about mathematics, mathematics teaching, and/or mathematics learning from their participation in

the institute. Because I wanted to understand how mathematics teachers made sense of their professional development experience, it was necessary that the participants experience some form of change in their knowledge and/or beliefs from the experience. This selection criteria was intended to optimize the chance that teacher development would occur in the context of practice without dictating the direction.

3. The participant was able and willing to be a part of this joint project. Experience and research have taught me that teacher development is difficult to study because it is both intentional and unintentional. Kagan (1992) cautions that "teachers can follow similar practices for very different reasons" (p. 62). Therefore, research on teacher development requires making inferences about teachers' intentions using a combination of teachers' voice and actions. This necessitated the teachers' availability and willingness to contribute to our understanding of the process of teacher development.

Prior to the institute, I examined all 23 mathematics teachers' pre-surveys, identifying 13 teachers with at least five years of teaching experience. During the first four days of the institute, I observed these 13 teachers' interactions and examined their journals looking for evidence of changes in their knowledge and beliefs. An example of evidence self-identified by Mia was: "algebra and geometry were really distinct in my head and now the lines are more blurred. There are many more connections between algebra and geometry than I previously had realized" (Post-Survey). By Friday, I had identified six target participants. Through informal conversations on Friday morning, I found out that two of these select teachers would not be available for follow-up, one due to summer commitments and one due to fall commitments. After the institute, I interviewed all four of the remaining teachers. I invited three of these teachers to participate because of their self-reported qualitative reorganizations of understanding identified explicitly by the teachers or inferred by the researcher through the teachers' intentions for their practice.

Data Collection

Data collection drew from multiple sources including observations, interviews, and teacher products (such as institute produced surveys, journals, and assignments) allowing for triangulation of information. Informal classroom and e-mail conversations also contributed to the data. I videotaped the lessons I observed and audiotaped the interviews. Videotapes were used for stimulated recall purposes to prepare interviews guides. The interview tapes were transcribed and coded.

Procedures

The participants attended and completed all course requirements for the institute from June 2, 2003-June 6, 2003. I observed all small and large group activities of the teachers' week-long institute experience constructing and expanding field notes of each day's activities. Teacher products were collected and examined. I reflected on and wrote about the inferences I made about some of the teachers' changes in knowledge of and beliefs about mathematics, mathematics teaching, and mathematics learning from their participation in the program. Based on the above method of selection, before the conclusion of the institute I identified and invited four of these teachers to participate in an initial interview.

Within two weeks of the conclusion of the institute (June 6, 2003-June 20, 2003), I conducted approximately one hour open-ended interviews [see Appendix A for First Interview Guide] with each of the four selected participants in order to identify (a) what contexts and understandings from their prior practice do teachers perceive as being significant to the changes in knowledge and beliefs they encountered during their professional development experience?; and (b) how they envisioned their future practice changing based on their professional development experience. The interviews were audio taped and transcribed. From these interviews, I selected and recruited three teachers to participate in the study; all three agreed to participate.

After the three participants returned to their schools, I observed and videotaped each of their classroom teaching experiences for two cycles of approximately one week. The first cycle was near the beginning of the school year (Sue: August 11^{th}-15, Mia: August 27^{th}-September 3^{rd}; and Lois: September 1^{st}-3^{rd}), and the second cycle was near the middle of the school year (Sue: November 3^{rd}-7^{th}, Mia: October 29^{th}, November, 13^{th}, and January 21^{st}-22^{nd}; and Lois: October 29^{th} and March 3^{rd}). The observations were documented by condensed field notes that were expanded daily. Following each observation cycle, I conducted one hour open-ended interview [see Appendix A for Second Interview Guide] with each participant in order to identify what they perceived they were able (or not able) to do in their practice (both envisioned and spontaneous). Based on my observations of their teaching, I attempted to uncover other impacts of the teachers' professional development experience on their classroom experiences that were not recognized by the teacher. Videotapes from the institute and classroom experiences were used for stimulated recall in formulating interview questions. The interviews were audio taped and transcribed. In addition, the participants provided follow-up data through informal conversations and e-mail.

Data Analysis and Representation

Data analysis was a continuous task from the beginning of the research study. Ongoing analysis of the transcripts, field notes, and teaching products was conducted to guide data collection and management. The focus of this study was on understanding how mathematics teachers, who had shown evidence of changes in their knowledge and beliefs, made sense of their professional development experiences in the context of their practice. I used two main phases of retrospective analysis: describing each participant's contextual experiences; and examining the process of development across participants.

The first phase of analysis was to identify each participant's experiences that served as the context for their development. Since I was examining how these teachers' constructed their development through the reflexive relationship between professional development and practice, it was important to create a description of each participant's institute and classroom experiences, as well as the contexts in which these were situated. I coded data in terms of its potential to inform me about each participant's institute, prior classroom, intended classroom, or actual classroom experiences.

In the second phase of analysis, I looked across participants at the components of teacher development. The work of Goldsmith & Schifter (1997) was instrumental in determining strategies for coding. For the first component, the authors used qualitative reorganizations of understanding as a means to discuss increasing differentiation of cognitive structures. In identifying each participant's qualitative reorganizations of understanding, I looked for their change or perceived change in knowledge and beliefs as well as their parallel preconceptions. Examples of this included: mathematics as connected rather than isolated; mathematics teaching as engaging rather than telling; and mathematics learning as understanding rather than memorizing. I coded data in terms of its potential to inform me about each participant's preexisting and newly reorganized understandings of mathematics, mathematics teaching, and mathematics learning. I described the state of each participant's individual knowledge and beliefs – their understandings of mathematics, mathematics teaching, and mathematics learning – at various points in time in their development. These parallel understandings are summarized in Tables 1, 2, and 3.

For the second component, orderly progression of stages, the authors suggested stages of development that teachers progress through as they attempt to make sense of, use, and build on their reorganized understandings in practice. Rather than mapping out the different pathways participants took as they developed, for this study investigating the orderliness of change involved mapping out global trends of mathematics teacher development among participants as they followed different directions of development. These trends included aspects of their making sense of, using, and building on their reorganized knowledge and beliefs from, for, and in practice. Looking across participants, I coded data as indicators of the dynamic between teachers' knowledge, beliefs, and practice, looking for that which was orderly about their process of development. I identified aspects of teacher development that are orderly across participants. This dynamic relationship is modeled in Figures 1, 2, and 3.

For the third component, the authors used transition mechanisms as a means to discuss mediators for the interplay between reorganizing understanding and practice. Psychological mechanisms are experiences, such as those in a professional development or classroom environment, which stimulate teachers to reorganize their understandings and practice. Sociocultural mechanisms are images and interactions, such as those from professional development and classroom experiences, that provide the context and support for reorganizing understanding and practice. In this study, I looked for psychological mechanisms that teachers used to resolve their conflicts between their understandings and their environment. This included identifying professional development experiences that stimulated my participants to reorganize their understanding and classroom experiences that were critical in reorganizing their understandings. Sociocultural mechanisms such as images from professional development experiences and classroom interactions are important in teacher development. In this study I looked for sociocultural mechanisms that provided the context and support for teachers as they reorganized their understandings and practice. This included looking for contextual aspects such as images from their professional development experience, and interactions with students and colleagues. Therefore, in this study I looked for the experiences that promoted development and the images and interactions that provided the context and support for their development. I coded data in terms of its capacity to inform me about their professional development and classroom experiences, their images from the institute, and their interactions with colleagues and students. I described the mechanisms that each participant attributed to their transition from one level of understanding to the next, paying attention to both psychological and sociocultural mechanisms.

For the fourth component, motivation and disposition, the authors referred to the affective issues that initiate, sustain, and influence development. In this study, I looked for motivational factors that led my participants to: reorganize their understandings, undertake the task of transforming their practice, and sustain their process of development. These included their desire to be liked by students, to motivate students, to satisfy school system initiatives, or to increase test scores. In addition, I identified particular interpersonal and intellectual orientations that influenced each participant's course of development. These dispositional factors included their abilities to: trust students' abilities, allow frustration, deal with uncertainty, and see themselves as authorities (Cooney & Shealy, 1997). I coded related data as indicators of initial motivations, sustaining motivations, and influencing dispositions. I described each participant's initial motivations for undertaking development, their sustaining motivations for continuing development, and their influencing dispositions for approaching and resolving developmental issues.

Each phase of analysis involved initial coding and focused coding (Charmaz, 2002). In the initial coding stage, I read the data from the interview transcripts, field notes, and teacher products, coding it line-by-line. I sorted the data by contexts (prior experience, institute experience, intended classroom experience, and actual classroom experience), using caution to monitor when and where the data arose, and in what context. After sorting the data temporally, I began focused coding by examining the data repeatedly to identify themes, using inductive analysis to look for confirming and disconfirming evidence. From these themes, I created a description of each participant's developmental experiences. Excerpts from the interviews were edited, without compromising the teachers' meaning, so sentences would read smoothly.

Research Issues

There are a few aspects of this study that are unique and must be considered by the reader. As the primary data collector and analyzer, the decisions I made, what I saw, the questions I asked, and how I interpreted the data were affected by my biases. One particular area of bias in this study was how I selected the participants. Because I was interested in how teachers develop, I purposefully chose teachers who showed evidence (identified explicitly by teachers or implicitly through their intentions) of changes in their knowledge and beliefs about mathematics, mathematics teaching, and/or mathematics learning. Therefore, the nature of this investigation is one in which I began with teachers' intentions. Although this choice optimized the chance that teacher development would occur, it limited what could be learned from this study.

I sought objectivity in this study by using my theoretical perspective and research framework as tools for data collection, analysis, and representation. In addition, I employed a variety of techniques to ensure reliability and validity of data and data analysis. First, in order to maintain and represent reliable information, I engaged in a nine-month relationship with participants, as well as systematic and thorough analysis of data, using caution to monitor where evidence arose and in what context. Second, I tried to build validity through purposeful sampling and triangulation of methods. Representations of teachers' development relied on participants' accounts of their development through interviews combined with my perspective of their development through observations and analysis.

CHAPTER 4

RESEARCH CONTEXTS

In this study, I investigated how teachers construct their development through the reflexive relationship between professional development and practice. This chapter provides a description of each participant's professional development and classroom experiences that served as the context for their development. Specifically, I addressed the following questions for each participant:

- In retrospect, what contexts and understandings from their prior experience do teachers perceive as being significant to the changes in knowledge and beliefs they encountered during their professional development experience?
- In projection, what meanings (both envisioned and spontaneous) do teachers construct for their intended classroom experience based on the changes in knowledge and beliefs they encountered during their professional development experience?
- In introspect, what do teachers do (or not do) in their actual classroom experience (both intentional and unintentional) based on the changes in knowledge and beliefs they encountered during their professional development experience?

The analysis is organized by participant around four contexts: prior experience, institute experience, intended classroom experience, and actual classroom experience.

Mia

Prior Experience

After teaching middle school mathematics in a large suburb for nine years, Mia registered for the institute to find ways to make mathematics more meaningful to her and her students. Having earned a degree in mathematics she felt confident about her ability to recite and apply formulas and definitions, but confessed that geometry was her weakest area. Mia considered herself to be moderately experienced at working with technology, having used it for daily work, to enrich lessons, present notes, and communicate with students (Pre-Survey). She had even used GSP one time at the end of the last school year.

> I had seen it done at a [workshop]. So, I wanted my kids to import a picture in and use Geometer's Sketchpad, because I thought that would be something neat, that they would enjoy. We took pictures of all the water fountains in the school, and then we put in the pictures and we just graphed them very simply by graphing the points and finding the equation on the calculator. (Interview, 6-18-03, Line 476)

Mia indicated that many mathematical software tools were available at her middle school.

Mathematics. Prior to the Institute, Mia defined mathematics (she referred specifically to arithmetic and algebra) as an objective subject that is meaningful (Pre-Survey). She talked about the origin of her viewing mathematics as a meaningful subject.

> I never understood what a function was until I taught math modeling. Math teachers say, "Just remember this definition. For every 'x' there's a unique 'y' or for every input there's a discreet, unique output." That means that if the same input gives you two different outputs, then that's not going to work, because you're not going to be able to

> draw any conclusions. But it never connected until I was up there teaching. It was like, "Oh, that's what a function is! (Interview, 6-18-03, Line 238).

To Mia, mathematics makes sense through applications. Because of its applicability, Mia perceived mathematics as having many paths to the right answer.

In contrast, Mia viewed geometry as a disconnected strand of mathematics that didn't make sense. To her, geometry was a set of deductive rules where "you learn a bunch of theorems, and write these little proofs, and you might be right, you might not. If you forget this one little rule, you're not going to get from here to there. That bridge is out!" (Interview, 6-18-03, Line 352). Because geometry was about memorizing definitions and theorems, Mia felt that there was only one path to the answer.

Mathematics teaching. Mia described her mathematics teaching style mainly as traditional in the sense that she was accustomed to lectures, quizzes, and projects (Transcripts, 9-03-03, Line 263). However, she viewed teaching as an opportunity to help students make sense of mathematics. She offered a couple of ways that she had facilitated students making sense of mathematics in her classroom. First, Mia prompted students to share multiple ways that they approached the same problem. For example, she talked about solving proportions, noting that some students cross multiply while others get common denominators. In addition to making sense out of the mathematics, she claimed that discussions such as these led to finding the most efficient way of doing problems. Second, Mia regularly gave students applications such as building a garden, pig notching, and water fountains. She firmly believed that mathematics and science courses should be better aligned in order to allow students to make connections between the mathematical skills they are learning and the science applications.

> I really wish the state of Georgia would get on the ball, and align math and science courses. I think a fantastic course would be first semester you learn all the skills. Second semester you do all the science. And you just pair them up. And now you're practicing all of those skills. The more applications I have to things in the outside world, the more it makes sense to children. (Interview, 6-18-03, Line 267)

Mia suggested that algebra should be paired with physical science and chemistry, geometry with biology, and calculus with physics. She felt that this pairing would allow students to learn mathematical skills and then practice them in real situations.

Mia's rationale for wanting students to understand mathematics is that when it makes sense, you remember it longer, you don't have to do as much practice, and you can figure things out without memorizing everything. So, to Mia, teaching mathematics meaningfully saves time, is more permanent, and flexible. This is very important to her because teachers don't have much time, and they are judged by how much students remember.

> There's this thing you have to cover. In high school it's often the textbook. In middle school you have this set of objectives you have to cover, and you have to get them done. If you don't, then you are not going to be seen as a good teacher. And you are going to have unhappy parents, you're going to have unhappy students, and you're going to have an unhappy administration. And those are the people you have to answer to. (Interview, 6-18-03, Line 378)

Mia compared teaching for meaning to covering the textbook or county objectives. "Another meaning of 'covering' is 'hiding'. And that doesn't make any sense. Covering is not what we want to do, we want them to actually learn it" (Interview, 1-22-04, Line 160). So, Mia identified a tension between teaching mathematics and covering the mathematics curriculum.

On the other hand, Mia viewed the teaching of geometry as just “a big vocabulary lesson.” She offered this as her rationale for geometry and biology being paired together, both are what she considers memorization courses. Her views of geometry impacted the importance she placed on teaching it. “We have so many students who have yet to master the basic computation skills that I wonder how important transverse angles and their like really are?” (Pre-Survey). In addition, Mia felt insecure about her artistic ability. Because of her self-identified spatial difficulties, she does not draw any kind of pictures on the board. “We draw on the graphing calculator, but I don’t do the drawing. Since I can’t do it, I just say, ‘Imagine it’” (Interview, 6-18-03, Line 458). For these reasons, she admitted that she never concentrated much on geometry objectives.

Mathematics learning. Prior to the institute, Mia claimed that she believed people learn mathematics in one of two ways. “They can either make sense of it, or they can practice so many problems, that they just see the problem and they know how to do it” (Interview, 9-03-03, Line 202). She claimed that when students are able to make sense of mathematics, less examples and practice are required. To Mia, making sense of mathematics comes from applications (Pre-Survey). She attributed this belief to her claim that she learned most of her mathematics from her science classes.

> I have no real recollection of math classes. Algebra I class, algebra II class, I don’t remember really learning in those. I remember learning in chemistry class, in physics class, and outside trying to build a cardboard boat, and trying to build some other things. I remember that’s how I learned a lot of things, because that’s where I had to actually apply it. (Interview, 9-03-03, Line 230)

Because Mia claimed that she learned mathematics through applications, she valued students learning in this way.

In addition, Mia believed that people learn mathematics through repetitive practice. She identified a time when she learned through the “drill and kill method”.

> I did not understand [related rates] the first time I took the AP calculus test. So, I practiced and memorized how to do the related rate problems that involved a balloon. And whenever I saw that balloon problem, I could do it. Not because I understood it, but because I had memorized the sequence and steps. I knew where to put the numbers, depending on what it said. (Transcripts, 9-03-03, Line 204).

Mia believed that memorizing and practicing is important, but recognized the limitations to this. “If you had to remember everything out there, you just couldn’t do it. You’d have to constantly be refreshing your memory (Transcripts, 9-03-03, Line 164). So, Mia used techniques, like singing songs, to help students remember things they must memorize.

Mia claimed that she is not a spatial learner.

> If I wanted to draw a circle, I had to draw it like 10 times, because I never get the compass right. And it was just very frustrating, and that’s another reason why it was not meaningful, is because I didn’t have the art skills that some other people had that made it more meaningful to them. (Interview, 6-18-03, Line 57)

So, in contrast, Mia believed that most people learn geometry differently than other strands of mathematics. She described her own experience of learning geometry:

> I’ve had three geometry classes, one in high school, one in college, and one in post-graduate… It was all the same sort of thing, “Learn a bunch of theorems, and write little

> essays." Like triangle ABC is congruent to triangle CDE because of CPCTC. That sort of thing. (Interview, 6-18-03, Line 245)

So, to Mia, Geometry is learned through memorizing and practicing.

Summer Institute Experience

Mia registered for the institute as part of her specialist degree program in Instructional Technology. She described the institute as a high school type geometry course with a twist.

> We were doing high school type geometry, except it wasn't, "Here's a list of theorems. Now take these and prove things." It was, "Okay, we're starting here, let's build on that, and let's use the technology and explore, what do you see? What can you figure out?" And everyone wanted to figure out the right answer, but there were no right answers at the institute. (Interview, 6-18-03, Line 7)

So, to Mia, the institute was a different kind of geometry course than she had experienced in the past. Not only were there open-ended applications of geometry to be explored, there were technologies available for tools in investigating these problems. And in addition, because the problems were open-ended, many problems had multiple answers and the goal became less about getting answers and more about building meaning.

Mathematics. During the institute, Mia's definition of geometry was challenged. Through the demonstration lessons and open-ended investigations, she began to view geometry as "the things that happen that make the algebra work" (Interview, 6-18-03, Line 302). She identified a demonstration lesson about a parabola as contributing to this change:

> The big thing for me was the parabola. I memorized the definition in Algebra II, and it just stuck there, but I had never really thought about it in geometric terms. It's hard to touch a parabola, but seeing it really helps. And now I understand what a directrix is and what a

> focus is and how it works. It just made so much more sense than just giving the definition. (Interview, 6-18-04, Line 86)

Mia claimed that her new conception of geometry made more sense to her because, “they didn’t come up with the quadratic equation and then write a parabola from it. We had a parabola, and from that, they made the algebra” (Transcripts, 9-03-03, Line 115). The GSP illustration helped her to visualize a concept that she had considered abstract. She claimed that in addition to giving her a better understanding of parabolas, this demonstration lesson challenged her view that geometry is about memorization. This view of geometry is more consistent with her broader view of mathematics as a subject, with a few exceptions. In the past Mia thought about mathematics as being meaningful through applications. During the institute she began to see mathematics as being meaningful through connections between different strands of mathematics. In addition, Mia began to think of mathematics as less of an objective subject, and more about visualizing and investigating.

Mathematics teaching. During the institute, Mia began to think differently about her mathematics teaching. First, she thought about ways she could help her students make sense out of geometry through applications, instead of just teaching vocabulary. As an example, she talked about how she might have taught parabolas:

> I wish I had known [in the past] some of the stuff at the institute. I would have had [my students] take pictures of satellite dishes, and had them find the focus, and them discover, “Oh, the focus is where the pointy thing is in the middle!” of that parabola picture. And give them a little bit more understanding of what those things are, as opposed to, “Okay, it’s an upside down ‘U’ or it’s a right side up ‘U’, and it’s some sort of an equation.” A

> much better feel for how it directly relates to them. And that's something I wish I had had, that I now have, that I can take back to my next classroom. (Transcripts, 6-18-03, Line 482)

So, Mia saw a connection between her new understanding of a parabola and the way she taught it.

Second, Mia thought about ways she could help students connect geometry with algebra. "We spend so much time trying to connect it with real life and not enough time trying to connect it with itself. We need to do a better job of letting kids see that the geometry connects with the algebra" (Interview, 6-18-03, Line 497). She admits that she has a hard time seeing connections between mathematics. She claims that for each connection she can make, she can bring this into her classroom.

Finally, Mia thought about ways she could better demonstrate geometry. First she began to think about how she could help students visualize geometric shapes. "If you can see the pictures of what happens, then what you're doing makes sense" (Interview, 6-18-03, Line 303). She planned to use GSP: "I will use GSP to give them the support to see the pictures, as opposed to telling them to imagine it. Knowing it didn't work with me, why I thought it would work with them is beyond me (Transcripts, 6-18-03, Line 454). She believed that by drawing and manipulating geometric shapes for her students, she would be better demonstrating geometric shapes. Second, Mia began to think about how she could help students discover geometric concepts. She distinguished between leading students to discover mathematics and using open-ended investigations. Although she enjoyed working the open-ended investigations at the institute, Mia claimed that she would never use this method in her classroom. Her rationale for this claim is that they were time consuming (Journal, 6-02-03) and they wouldn't provide evidence that students had learned the objective of the lesson (Interview, 6-18-03, Line 385). So, Mia's thinking about teaching changed to include demonstrations that help students visualize geometric shapes and discover predetermined geometric concepts, but did not include open-ended investigations.

Mathematics learning. During the institute, Mia reconsidered her view of how mathematics is learned. Mainly, she began to view exploration as an additional way to learn mathematics. Through exploring at the institute, she found that many concepts were built from one starting point (Transcripts, 6-18-03, Line 15). In addition, she decided that she really is a visual learner, but that her artistic abilities had always hindered her from realizing this. "The things that I could not do were taken away, so then I could look at, and I could see what was going on" (Interview, 6-18-03, Line 68). She claimed that by being able to visualize geometry, the concepts became more accessible and relevant to her.

Intended Classroom Experience

In the fall following the institute, Mia began teaching high school mathematics in a small rural county. In addition to her anxieties about teaching at a new school, the 9th grade courses she was teaching were module-based, which she claimed to be unfamiliar territory for her (Interview, 6-18-03). Mia indicated that she would be the only "gifted certified" teacher in the 9th grade academy, and therefore predicted that she would probably be teaching both algebra and geometry. She was uncertain of the available technology at her new high school.

Making connections. Mia stated that in the fall, she wanted to do a better job of showing her students how geometry and algebra connect. "For every connection I can make, I can give it to my students" (Interview, 6-18-03, Line 267). Among these, she mentioned the connection between algebraic formulas, geometric definitions, and visual representations. Specifically, she mentioned the connection that she had seen at the institute between the definition of a parabola and its visual representation.

> Like with the connection with the parabola. "Now I understand what those things are doing, and why they're there." And before, they were just these words that I knew existed. And so, the more connections I know, the more I can bring into my classroom and show the kids and say, "This is how it works, and this is what you're doing. Now let's look at what you've made, and what's out there."(Line 294)

So, Mia valued sharing her new connections with her students.

Even though Mia now values making connections between geometry and algebra, she expressed some concerns about being able to enact this in her classroom. First of all, she was concerned about seeing connections. Specifically, she was uncertain about her own knowledge of connections between the two strands. In addition, she feared that teaching a new curriculum at a new school may be too overwhelming for her to concentrate on integrating this into her teaching. "It's hard to overcome [how we teach] sometimes. Especially when you're new, or when you're teaching a new subject, or you're doing something different" (Interview, 6-18-03, Line 334). But, even with these reservations, Mia intended to incorporate more connections between algebra and geometry into her teaching in the fall.

Using investigations. Mia claimed that although she enjoyed learning mathematics through the open-ended investigations at the institute, she was certain that she would not use problems of this nature with her students. "Open-ended problems are hard to use in classrooms because of time constraints" (Journal, 6-2-03). She clarifies her concern: "you may not ever get to the objective you're actually trying to learn because you may go off on another tangent with an open-ended problem" (Interview, 6-18-03, Line 383). Instead, she described a modified approach to using investigations that she intended to use.

> I'm hoping that I can sort of lead them to discovering it by putting it up, sort of like [the professor] did when he put it up and he kind of said, "Now look at it this way. Instead of starting out with the quadrilaterals, let's start out with the diagonals. Now where are we going?" Trying to lead the kids in getting them to make some connections in their own minds. (Interview, 6-18-03, Line 166)

So, Mia's intentions for using investigations were to guide students to discovering particular objectives through teacher directed constructions, manipulations, and hypothesizing. Mia hoped that many of the geometry modules would lend themselves to investigations of this nature.

Using technology. In the fall, Mia intended to incorporate more technology into her teaching. Specifically, she planned to use GSP for demonstration purposes to help her students better visualize abstract concepts such as a parabola. "If you can see the pictures of what happens, then what you're doing makes sense" (Interview, 6-18-03, Line 303). She described how she intended for this to look in her classroom:

> I think the way it will look is, they will get to see some better drawings, because I am more secure that I can make it look like it's supposed to look instead of making them imagine what it would look like. I can show a straight line, or I can show a triangle and how you can change its angles (Interview, 6-18-03, Line 454).

Mia claimed that her new comfort with GSP would allow her to visually represent geometry in ways that she was unable to in the past. Because she now valued visual representations as part of the learning process, especially with geometry, Mia felt that GSP was a necessary part of accomplishing this (Post-Survey).

Actual Classroom Experience

Mia began the school year teaching 9th grade Algebra I. Even though the previous year, all 8th grade students had taken Algebra I, none had passed the end of course exam. So, this year all 9th grade students were repeating Algebra I using a module approach, in which they would work on the algebra strands that they answered incorrectly on the exam. She described her beginning experience with this approach:

> Instead of teaching a [common] unit and then testing, the kids work on the units they have not mastered. So all of my students are really doing different things, and I'm doing what I think all of them could benefit from when I do actual teaching. And the rest of the time I'm almost acting like a personal tutor, working with them on things they didn't know, checking and making sure they're doing it correctly. (Interview, 9-03-03, Line 7)

So, at the beginning of the year, Mia saw her teaching role as one in which she worked daily with each student on their individually assigned tasks, with minimal group instruction. She compared this approach to her experience at the institute:

> This summer we picked the problems we wanted to work on, and then examined and analyzed them. The professors made sure you were on the right track, and they would do different examples to sort of guide you over things that they wanted you to know. But it was your motivation and your interest, which propelled you forward. (Interview, 9-03-03, Line 17).

She claimed that the institute was a useful source for her facilitating the learning environment. "What I'm trying to do is learn from the way they had it set up, the way they talked to us. Our goal is to mirror what they did this summer where we had some instruction, but mainly it was, 'Go to it. Figure it out'" (Interview, 6-18-09, Line 163). She even contacted the professor to learn more about how he did it (Interview, 1-22-04, Line 73).

Because the modular approach to teaching has every student at a different place. Mia felt like she was "flying by the seat of her pants" (Interview, 9-03-03, Line 29). Specifically, she didn't feel like she had a handle on where all of her students were at one time. In addition, because students taught themselves from the book, she felt that students were missing out on many things they needed to know and be able to do. Mia offered these reasons for why she felt she had to "fall back and punt" by teaching equation manipulation instead of meeting her intentions. "My goal right now is to just survive and not go crazy" (Interview, 9-03-03, Line 279).

As the year progressed, Mia found ways to modify the modular approach that she felt would better meet her and her students' needs. Some of the changes she made included daily lectures and required homework and quizzes in addition to the module assignments. Mia claimed that by making modifications to the modules, she was able to begin incorporating some of her new goals into her teaching.

In addition, during the second semester, Mia began teaching a geometry course for those students that had finished the Algebra I course.

> The nice thing with the geometry is there's only 10 units, and a lot of them are things that the kids should already know. These students are very bright, they catch on quickly. Plus, in the module program, there are no modules for algebra II, so once they finish geometry, there is no place for them to go. So I have a lot more time in that class to spend.

The reduced number of objectives, high student motivation, and nearing completion of the module program made Mia feel confident in her ability to experiment with new strategies.

However, Mia felt hindered from realizing some of her goals in her other classes because she had too much to cover, and students that are less receptive to learning in different ways.

Making connections. During the first semester, Mia claimed that she was not able to realize her intention to make connections between geometry and algebra in her teaching. However, she claimed that "when I have to teach the geometry, I'm going to have to do something else to make some of those mathematical connections" (Transcripts, 9-03-03, Line 53). Even though Mia was unable to connect geometry to her algebra courses, she was able to continue applying mathematics. For example, Mia shared that:

> Yesterday we talked about, " Y is a function of X." It's never really spelled out in a math book what that means. And knowing Y is a function of X, directly relates to chemistry and physics, because understanding that that's just a translation of dependent and independent variables is very important. But without that, students can't make the connections between the sciences and the mathematics that they're learning. (Interview, 9-03-03, Line 38)

Mia made students stop working on their modules when she gave them connections between the mathematics and the science.

As the second semester began, Mia found that she was able to start making connections within algebra.

> Before, I felt like I couldn't ask any questions that everybody hadn't gotten past. Now I feel like I can ask "Why do you have to flip the sign? What are the actual steps for solving that problem if you couldn't flip the sign?" Or, "How does the distance formula come from the Pythagorean Theorem?" And I feel like that gives them a little bit more understanding of what's going on. (Interview, 1-22-04, Line 59)

In addition, Mia did find ways to bring algebra into her geometry course. She gave an example of an algebra problem that she came up with for her geometry students:

> I wanted them to see the distance formula and to make the connection that they put in some random points, then suddenly they've now got a circle, which is the set of all point that is equidistant from the center. So, to see that if I replace distance with the radius, I now have the formula for a circle that they're going to apply in algebra II when they talk about conic sections. (Interview, 1-22-04, Line 99)

Even though she was able to begin making connections within algebra, and from algebra into geometry, she didn't bring in the geometry to the algebra, not even what she had learned from the parabola demonstration during the institute. She talked about her inability to draw geometric connections into her algebra courses:

> I did not use geometry to help algebra make sense because I've never been taught that way. There was nobody that ever sat down and showed me the connections, 'Okay, this is where it comes from', and I didn't sit around and think about it. I mean, like this circle thing was something I realized, "Oh, that's the equation of a circle!" So, I've not made the connections myself. [But], because I have taught algebra and I'm so comfortable with it, I can make the connections. (Interview, 1-22-04, Line 217)

So Mia points at her own comfort with algebra as contributing to her incorporating algebra into geometry. However, because she is still unfamiliar with geometry, having never taught the course before, she is apprehensive of making connections in the reverse order. She predicted that in the future, after having taught geometry, she would probably be able to make more connections with geometry in her algebra courses.

Using investigations. At first, Mia was not able to incorporate investigations into her practice. Even though she felt confident in her ability to lead students in a "discovery type" lesson, she did not feel that the modules lent themselves to this type of instruction. However, as she began to modify her approach to the module teaching, she began to find ways to accomplish this with her geometry class.

> So my idea with the investigations, by plugging them in my geometry class, it makes them explore and it makes them think about it. Which all of these kids like to do anyway. And so I'm trying to teach them better, by having them explore and figure out.

Because her geometry students are receptive to investigating, Mia felt challenged to incorporate investigations into her geometry class. She talked about the origin of this value:

> We were talking about the undefined terms in math and how undefined terms work, and I had one student say, "Okay, fine. I want to start my own math. Now we're going to look at what happens when two points make a curve instead of a line." At the end of the period he had has own little 'math', with his own little rules, starting out with a little bit that Euclid had talked about with a point. He had his 3 undefined terms and then was trying to build on them from there. Which in that 'math' adding didn't work, but he hadn't gotten there yet. (Interview, 1-22-04, Line 139)

Even though Mia valued investigating in her geometry classes, she claimed that she would not do any investigations in her other classes because she had too many objectives to cover, and students that were not interested in thinking that way.

Using technology. During the first semester, Mia had trouble incorporating technology into her algebra courses. For one thing, the computer labs at her new school were used daily as classrooms. In addition, her lack of geometric objectives took away her need for using GSP.

However, by the second semester, Mia overcame these barriers. She was teaching geometry and she was able to make arrangements to use the computer lab once a week. She talked about her progress. “I had to learn who people were, be confident enough to go ask if I could do that, and all those sorts of things which at the beginning of the year you’re not” (Interview, 1-22-04, Line 322).

Mia had students spend two class periods learning the software. “These kids catch on quickly. They figured out, without any sort of tutorial, how to animate (Interview, 1-22-04, Line 129). In the next few weeks, she planned on having students start investigations on triangles. “I am going to assign each group of two an investigation that they will work together and then present what they come up with to the class” (Interview, 1-22-04, Line 180). She described her experience:

> What makes me happy, is how excited the kids are, and how they’re already figuring things out about circles and about lines that they probably wouldn’t have figured out because they wouldn’t have sat down and drawn it with a compass and a straight edge 50 times to figure out whatever they were going to figure out. Because you can just sit and play with it. And they were discovering things they didn’t know yet. And later on we’ll make that connection to the math that we’re learning.

Even though Mia has had some problems with the technology, specifically with the computers being slow and unreliable, she feels what the students are gaining from the experience outweighs the cost.

Sue

Prior Experience

Sue has taught elementary school mathematics in a small suburban county for 14 years, and recently earned a specialist degree in mathematics education. She claimed that through these experiences, she learned: “a great deal [about] mathematics, how students learn mathematics, and the importance of providing them with early experiences they can build upon as they get older” (Pre-Survey). Sue considered herself to have had pretty extensive experience with technology and her elementary school had many mathematics software programs available, both in her classroom and in a computer lab.

Mathematics. Prior to the institute, Sue viewed mathematics as problem solving. She described problem solving as entailing more than the computational practice found in textbook word problems. “‘Mary has four apples, John has three. How many do they have in all?’ That’s not a problem!” (Interview, 8-14-03, Line 20). Instead, to Sue, problem solving was about finding patterns in real-life situations. She described a problem that she had in a prior mathematics course: “Find the maximum number of pieces of pizza you can have with a given number of straight cuts?” Sue considered this problem the origin of her definition of problem solving because finding the answer involved more than the application of a particular algorithm. But, “at the end, it’s either right or it’s wrong” (Interview, 6-9-03, Line 66). So, to Sue, success in mathematics was finding answers to problem solving situations.

Even though Sue viewed mathematics as problem solving, prior to the institute she expressed concern that at the elementary level geometry is typically viewed as “knowing the names of shapes, and how to use a ruler” (Pre-Survey). Because geometry was about memorizing names of shapes and procedures for using a ruler, Sue felt that geometry was disconnected from the other strands of mathematics, and in particular from problem solving. So, Sue had concerns about the importance of geometry.

Mathematics teaching. Prior to the institute, Sue described her mathematics teaching style as hands-on in the sense that she used technology and other materials for actively engaging with mathematics concepts. “They [Sue’s second graders] draw the shapes, they trace the shapes, they make the shapes on geoboards. I’ve even used GSP and let them draw shapes (Interview, 6-9-03, Line 260). In addition, Sue had always incorporated mathematical problem solving activities into her teaching. “I pride myself that I do problem solving with my students” (Interview, 6-9-03, line 88). Sue claimed that by focusing less on formulas and more on problem solving, she was providing students with life skills. “Twenty years from now, no one will ask you “What’s the formula for the circumference of a circle?” But if you’re sitting at home and your sink stops up, knowing how to solve problems is much more important than knowing information and facts” (Interview, 6-9-03, Line 88). So, to Sue, teaching mathematics involved providing students with hands-on activities and problem solving situations.

On the other hand, even though Sue provided hands-on experiences with shapes and measurement, she didn’t focus on problem solving with geometric concepts. “I’m guilty of standing up there saying, ‘Here’s a rectangle, and it has two long sides and two short sides. I think because I took it for granted that they already knew that kind of thing by the time they got to me, so it was just this quick little review and let’s go on” (Interview, 6-9-03, Line 280). Compared to other strands of mathematics that she regularly taught through problem solving activities, Sue felt like she preached geometry, and spent less time on it in order to move on to more interesting mathematics that she was more confident about.

Sue expressed concern about some of her prior students who she considered to be unsuccessful at school.

> It bothers me that at such a young age, I have children who already thought school was too hard. I had this little boy who did not understand the basics of subtraction. I know I got frustrated with him at times because it was just so frustrating! (Interview, 6-9-03, Line 227).

So, prior to the institute, Sue had concerns both about how she taught geometry and about how she interacted with students, particularly those that she considered to be unsuccessful.

Mathematics learning. Prior to the institute, Sue claimed that mathematics learning is constructed. Sue defined constructivism as "giving students the freedom and opportunity to build upon their own knowledge of mathematics and create their own understanding" (Journal, 6-3-03). She added that:

> MAP (mathematical perspective) theory furthers this idea by encouraging teachers to listen carefully to students and facilitate their mathematical understanding, while watching carefully for misconceptions and planning activities that will help students build on what they have already learned. (Journal, 6-3-03)

Sue related her view of how mathematics is learned to her own experiences in learning mathematics. First, she claimed that she typically learns mathematics differently than others.

> As a learner myself, I've been that person in class that someone says "That's not right! You can't do it that way." And my way was right. It wasn't their way, it might not have been the book way, but my way was correct, I ended up with the same answer, and I did it a different way. (Interview, 8-14-03, Line 127)

Second, Sue claimed that she learns best "by doing" (Pre-Survey).

> Everything that I do, as far as planning for them for math or for anything, I think about myself as a learner. And how I learn, and what experiences were valuable and rich to me. And the things that were valuable and rich to me were not things when I opened a textbook and wrote something down. (Interview, 8-14-03, Line 239)

So, based on her own prior experiences in learning mathematics, Sue claimed that mathematics learning is getting answers through individual activity, where individual means in your own way, and activity means doing.

Summer Institute Experience

Sue registered for the institute as part of her elementary education doctoral program. On the first day of the institute, she was nervous about the level of the mathematics. "I am concerned that the mathematics will go quickly over my head" (Journal, 6-2-03). Because the course was titled "Geometry for Middle School Teachers", as an elementary school teacher, Sue assumed that everyone else knew more mathematics and that she would not be able to keep up with them. But, as the week progressed, Sue began to realize that the institute was not about her keeping up with everyone else, but about her own growth. "It was like my own personal learning experience. I was in control of it, and I had all of these people to help me learn" (Interview, 6-9-03, line 106).

By the end of the week, Sue described the institute as a learning environment that challenged and supported her to build on the mathematics she already knew. "It was, 'Find something that interests you and keep going with it'" (Interview, 6-9-03, Line 100). Sue referred many times to the importance she placed on the support system at the institute. "I realized that I'm sure there were people in there that probably got frustrated with me because I asked them the same question 22 times! But they kept answering it, and they were patient with me, and they kept encouraging me (Interview, 6-9-03, Line 232).

Sue compared her experience at the institute to previous professional development courses she had attended.

> "I felt like it was an opportunity for me to learn instead of someone just trying to fill me up with information. So much professional development is "here's a new technique", or "follow this model". "Now go try it!" That's not what this was. It was about building passion into what you believe, and it just becomes part of you.
>
> Then you can make it your own. (Transcripts, 06-09-03, line 6)

So, to Sue, the institute was a different kind of professional development; one in which she was provided support for personally defined growth rather than being filled up with a static body of information, techniques, or models.

Mathematics. During the institute, Sue claimed to have learned a variety of new concepts.

> People always say, You know a square is really a rhombus which is really a…"
>
> That never made any sense to me! I didn't see it, but now I see it because I did it! I took parallel lines and I made a parallelogram and then I figured out all the properties of the parallelogram, and I compared them to the properties of a rectangle, and I started thinking about diagonals, and I had the "if/then" kind of a statement that I couldn't make before. (Interview, 6-9-03, Line 273)

As Sue expanded her understanding about the properties of and connections between shapes, she began to think about geometry as more than knowing names of shapes and how to measure. Although this knowledge was not fully developed, as evidenced by her defining a rectangle as two long sides and two short sides, she felt more confident in her knowledge of geometry.

In addition to deepening her understanding of geometry at the institute, Sue's definition of mathematics as problem solving was challenged. She identified the following open-ended investigation as contributing to this change: "How can you divide a circle into five equal parts" (Interview, 6-9-03, Line 137). As she found multiple ways to divide a circle into equal parts, she came to realize that problems don't have to be about getting the right answers.

> A year ago, if I had done that activity one way, I would have thought I was done. And through this, it's not the answer, it's the process and it's the building and the scaffolding of your knowledge into a new situation. And realizing that maybe there's never really an answer. That one thing leads to another, and it's kind of like peeling the layers off an onion. And you just find another layer underneath it, so that what you see at first is very simplistic and then the further you get into it you realize all the little complexities and all the ways that things link together. (Interview, 6-9-03, Line 54)

She began to see the value in opening up problems so that the focus is more on the process and connections between topics than on getting "the right answer."

Sue identified another problem, to construct a square with the same area as a given triangle, as further supporting her valuing of process and connections. "It was like cards falling on top of each other, it started all fitting together. The whole understanding of a difficult problem came from the simple activity of dividing a circle" (Interview, 6-09-03). Thus, the institute challenged Sue's definition of mathematics as finding answers to problem solving situations. Even though she continued to value problem solving with multiple paths, she began to consider open-ended situations that involve connections to other topics.

Mathematics teaching. During the institute, Sue began to think differently about her teaching. First, Sue wanted students to experience geometry through problem solving and connections rather than just hands-on shape making and measuring.

> We never got into the use of those shapes and the connectedness of those shapes. If there was some way that they could discover the shape, then they could discover the properties of the shape, and they could discover the definitions of the shape. The way that I discovered my own definitions and properties about geometry, about circles, about squares and quadrilaterals and polygons and all those things. (Interview, 6-9-03, Line 270)

Because Sue became aware of the connections between the shapes, in the fall she is "interested in doing more with quadrilaterals and polygons" (Post-Survey, 6-9-03). So, to Sue, exploring geometry now included applying and connecting in addition to the hands-on experiences she already provided.

In addition, Sue began to realize the importance of the classroom environment. She recognized that in the past many of her second graders felt like she felt at the beginning of the institute. "There's so many kids that walk into school the first day and they felt like I felt on Monday. "I can't do it. Everybody else is smarter than me. Everybody else knows more than me." And I didn't leave feeling that way" (06-09-03, line 215). She claimed that her own experience as a student in a learning community where she was supported and encouraged contributed to her passion in restructuring her own classroom to help students love learning.

> "This is how I felt, now I want to make my kids feel like this!" I realized that it's cool to be in an environment where you feel like you're learning and supported. So now I feel like I've got to go back to my room and I've got to do that (Interview 6-9-03, Line 193).

So, Sue's thinking about teaching changed to include supporting students to make connections and applications through open-ended investigating.

Mathematics learning. During the institute, Sue modified her understanding of how mathematics is learned. Mainly, she began to view constructivism as taking charge of constructing your own learning in a community rather than just individual activity. "I learned for myself that I can take control of my own learning" (Interview, 6-9-03, Line 44), and "When we came into that room on Monday, we were 24 individuals. But when we left, we were this working group. It was like we were a big 'think tank'" (Interview, 6-9-03, Line 204).

Also, Sue began to think about how different groups of students learn. Specifically, she focused on "struggling" students, because even though she considered herself to be a struggler at the institute, she was still able to be successful. So, Sue decided that learning mathematics for these students involves patience, persistence, and variety, rather than just repetition.

> I just kept thinking about those little struggling students, and what I could do to support them. It made me think about any child I've ever taught that didn't learn something the first time. And that you have to come at it different ways. (Interview, 6-9-03, Line 229)

So, from her own experience as a student at the institute, Sue reconsidered her view of how mathematics is learned to include taking charge of your own learning and support.

Intended Classroom Experience

In the fall, Sue would begin her 15th year of teaching, returning to the same elementary school she had taught at in the past. Since the institute was for middle school teachers, she expressed some concern with knowing how to apply what she had learned to her second grade classroom. “I’m not sure how to do it with second graders” (Interview, 6-9-03, Line 78). She added:

> My students don’t need to understand how to bisect a circle and create sectors of an arc. That’s not applicable for my age child. They don’t need to know everything I know, but because I know this much, I can better help them learn what’s applicable for them. (Interview, 6-9-03, Line 294).

Recognizing that its not going to be an easy task, she claimed that she had three main goals for her classroom: incorporating open-ended problems, building a classroom community dedicated to learning, and structuring a supportive classroom culture.

Open-ended problems. Sue claimed that in the fall, she wanted to make “everything very open-ended” (Interview, 6-9-03, Line 69). As examples, she talked about letting students experience some of the activities that she did during the institute such as discovering the properties and formulas for shapes.

> If I could come up with ways they could experience the shape, like inventing their own formulas. Or, if there was some way that I could let the children discover a square inside of something else. Even if it was a matter of I had a construction on GSP already set for them, and then I would say, “Now how can you use this to make something else?” Or I set it up as a problem. But if there was some way that they could discover the shape, then they could discover the properties of the shape, and they could discover the definitions of the shape.

> The way that I discovered my own definitions and properties about circles, quadrilaterals and other polygons. (Interview, 6-9-03, Line 266)

Even though she was uncertain about how to use open-ended problems with her second graders, she felt confident that she would do it and that her students would be successful.

Learning community. Because of her experience at the institute, in the fall Sue intended to build a classroom community that was dedicated to learning.

> It's not just about teaching a subject matter, it's the climate that my children feel when they walk into the room. I have to work to build that love of learning into them, it's creating a passion inside of a child. "This is how I felt, now I want to make my kids feel like this!" (Interview, 6-9-03, Line 185)

From her experience, she realized that this is something that doesn't happen naturally, she would have to work at it. "I used to think it was something that just happened, but now I realize that I have to come up with a way of structuring that to encourage it to happen" (Interview, 6-9-03, Line 202). She proposed some ways that she planned to build the learning community of her classroom.

> It's me coming up with a structure for developing that in my children, if it's giving them activities where they can find success in learning in a group. Where they feel like they are in control of their learning. Or maybe it means me telling them about my experience. So that maybe they'll see, "If the teacher can learn something and she's an old woman, then I can learn something, too." (Interview, 6-9-03, Line 199)

So, to Sue, building a learning community is more about the climate that she develops. Since she enjoyed and thrived in the climate of the institute, Sue wanted to structure her classroom environment to encourage each individual child to be in control of their learning in a community.

Classroom culture. Sue stated that in the fall, she wanted to begin the year structuring a supportive classroom culture. “I want to start on the first day of school with the goal that every child leaves my classroom saying, “You know what? I didn’t think I could learn, but now I know I can” (Interview, 6-9-03, Line 212). Later she added “I realize more than any subject matter that I share with my students, it’s those internal life skills that they carry away with them” (Interview, 6-9-03, Line 87). In particular, she wanted to focus on her struggling students

> I think that when I get ready to get frustrated with a child who’s struggling, I’m going to say, “No, wait. Nobody yelled at me. Nobody got frustrated with me. Nobody walked away from me.” It’s okay for them to ask me the same question a hundred times. But maybe after they’ve asked me a hundred times, they’ll understand on the hundred and first time. So I think next year when I have those little strugglers, I won’t tell them the same thing 10 times, I’ll help them find 10 different ways to do it. (Interview, 6-9-03, Line 226)

So, to Sue, structuring a supportive classroom culture involves being patient with students and providing them with a variety of different strategies.

Actual Classroom Experience

Sue began the new school year with her self contained 2nd grade. Upon returning, she learned that her elementary school’s focus for the school year was on building vocabulary. She described this initiative:

> The school improvement plan this year is that Learning Focused Schools program. One of the ideas that came about from that was to expose the children to lots of vocabulary, to make sure they have word walls, and they’re using the words. So I set up these areas where I’m putting content specific vocabulary words. (Interview, 8-14-03, Line 14)

In addition, Sue stated that she wanted to "keep up her momentum by focusing on the big goals that are above the curriculum" (Interview, 8-14-03, Line 180), like problem solving. She feared that she would get caught up in the things she had to do, like lecturing, doing book work, and giving assessments, that she would loose track of the things she intended to do.

> I have to show that I've used the book and that the children have mastered those objectives. And so I'm kind of stuck between what I want to do and what I have to do. I'm going to strike a balance in that I can use my math time to look at those big concepts in math, and then the book stuff will come, because it doesn't take long. And then I've kind of made everybody happy, so to speak. Me, mostly! Because I'm doing what I want to do! I think it will all, at the end, shake itself out. And I will have covered as much or more than other people, because it will be the depth as opposed to the width of it (Interview, 8-14-03, Line 190)

So, Sue began the school year confident that she could accomplish her new goals in addition to the other goals she felt required to meet.

Open-ended problems. From the first day of school, Sue worked on problem solving skills with her students. "I felt like last year I waited to do that. So I'm jumping right in, to kind of let them get the idea of what it's like to solve a problem" (Interview, 8-14-03, Line 18). She posed many closed-ended problem solving situations, prompting students to find different ways to get the answers.

> At this age, they're real egocentric. They think that their first way is the only way. I want them to understand that there's not one way to do something. And that it really doesn't matter *how* you solve something, whatever it is, as it's just that you can do it, that you

> understand how you did it, and that you can explain it or justify it. By having different children share different ways that they've solved things or ways that they've thought about something, I think it helps all the children, because it encourages them to be creative and different. And I think also they understand that if they are solving a problem or they're doing something and they hit a roadblock, they can always back up and go a different way. (Interview, 8-14-03, Line 39)

At first, Sue was unsuccessful with getting students to offer different ways to get the answer; however, she quickly began to see changes.

> I really thought when they did their name patterns that some child would notice, "If you count the letters in your name, and you count the letters in the Unifix cubes, you can match them up!" I just knew somebody would say that; but they didn't notice it. But, later when we did the skip-counting, they started noticing all these different ways, and it carried over from one day to the next. (Interview, 8-14-03, Line 83)

Even though Sue was able to begin the year by focusing on getting answers to problem solving using multiple methods, her intention to make everything open ended was not realized. However, as the year progressed, Sue began to find ways to open up the problem solving situations, such as the nine's problem:

> We were working on adding nine to numbers. Normally I would tell them that you can use the number you're adding to the nine to make a relationship. Instead, I put all the nine's addition tables on the board and said, "Look at them. Tell me what you see." I didn't tell them, and it was killing me not to tell them. But, it was kind of interesting because they saw other relationships that I hadn't thought about. (Interview, 11-7-03, Line 92)

Sue added that in geometry, she had students writing about the properties of triangles and squares, and sorting them based on their properties. She described an activity she recently did with her students:

> I said, “How do you know that’s a square?” And they say, “Well, it’s got four sides, it’s got four points or corners.” And so they were starting to figure that out. For some of the children I went over and kind of changed the position of the rubber bands and said, “Is this still a square? Do you think that’s still a square?” (Interview, 11-7-03, Line 31)

She talked about how this differed from her teaching in the past.

> I would have defined it for them, and I really struggled not to tell them, I wanted them to figure it out. So I have to kind of keep myself in check, which is hard because you feel like you need to tell them things. But they can discover it on their own, and I notice some of them figuring it out. (Interview, 11-7-03, Line 28)

Specifically, Sue struggled with some students that she felt weren’t ready for these kinds of activities. “They just needed to figure out what a square was, as opposed to rearranging angles and corners and all of those kinds of things” (Interview, 11-7-03, Line 34).

Sue identified some struggles she had with using open-ended problems.

> They were calling the triangles skinny, or fat, or slanty. Some kids even said that the triangle was upside down. This is their way of organizing it in their mind, but that they can understand that they’re all triangles, that it doesn’t matter how it looks as long as it meets those properties of a triangle, it’s a triangle. But, when we got to squares, they had to deal with the same issues with, “Well, is this still a square if it’s slanty? Is this still a square if it’s turned?” (Interview, 11-7-03, Line 13)

Sue talked about how she was able to persist with working on open-ended problems even though she struggled. “Well, I think [I’ve persisted] because of the kind of learner that I am. It’s that you just have to be tenacious, and you can’t give up, and you just keep trying. If one way doesn’t work, you try another way.” (Interview, 11-7-03). So, Sue identified her own tenacity as a learner as a characteristic that is important to implementing her goals.

Learning community. From the beginning of the year, Sue made plans for building a learning community in her classroom.

> I’m very excited about things that I’m planning. I’ve been looking at my NCTM book, and I’ve tried to come up with some big project or activity, that the kids could just get in there and think about it and work on it and talk about it. My kids are going to learn to be capable, to find out there are many different ways to do the same thing, they are going to have fun, and they are going to remember it.” When I open up the math book and look at page 2 and 3, I go, “They aren’t going to remember a whole lot of this.” Hopefully as I’m planning things, I can keep those things in mind, so it’ll be a valuable experience to them. (Interview, 8-14-03, Line 219)

So, at first, building a learning community meant planning a few memorable experiences above the daily activities of the classroom such as book work and assessment. But as the year progressed, Sue began to find more opportunities for students to take control of their own learning than just during special projects or activities.

> I’ve been giving them lots of opportunities to explore, write, and discuss with other children what they’re learning, because that helps them build on what they already know. And just kind of pulling myself out of it. (Interview, 11-7-03, Line 65)

So, building a learning community became more of a daily practice of getting students to talk about mathematics rather than relying on her telling them. Sue clarified how this learning community differed from her prior teaching.

> It's really changing from the way I normally do it. Letting them take control of it first, and talk about what they've learned, and share with one another because they learn so much more from one another. There's always that one child that figures it out really quick, and they'll tell a couple of more kids, and then it just kind of spreads out! (Interview, 11-7-03, Line 58)

So, rather than having students rely on her interactions with them, students rely more on themselves and each other for learning.

Even though Sue had success with building a learning community, she mentioned some struggles that she faced.

> It really is a struggle, because it's very different from the way I normally have done things. I'm always afraid that maybe I don't know enough. Am I telling them something wrong? It terrifies me. I start to second guess myself. Before I say anything, I think, "Okay, wait. I need to go back and double-check," that I'm telling them that correctly. So that's the scary part of turning children loose, so to speak, is they may ask me a question that I don't know the answer, or I'm not sure. (Interview, 11-7-03, Line 70)

In addition to her own insecurities, she struggled with students not being used to this kind of learning environment. "If I questioned them, they changed their answer! Like if it was a *true or false*, and I'd say, "Now, tell me why you think that's true." They erased it and put false" (Interview, 11-7-03, Line 166).

Sue talked about how she persisted through these struggles. First she talked about how she handled her own insecurities.

> We were discussing something the other day and I said, "I don't know. I have to go check that. Let me check it on the Internet." And I went over and looked for something on the Internet, and one of them said, "Well, can we look in the dictionary? Can we look in the encyclopedia? Let me check the science book." And everybody's looking for information. So it really kind of puts us all on that even playing field, that we're all teachers and we're all learners. (Interview, 11-7-03, Line 79)

So, even through this insecurity, she was able to build the learning community that she wanted. In addition, she talked about how she handled her students insecurities.

> It was a LOT of work at first. I just tried to stay patient, and not give in to telling them an answer, or just accepting an answer. I would model my thinking to them. "When I'm doing this, this is what I think about." And as I've done that, then they've become more comfortable with it. But it's been difficult to pull myself out of it and let them talk more and me talk less. (Interview, 11-7-03, Line 170)

From these insecurities, Sue had built a learning community where she was comfortable giving up control and her students taking this control.

Classroom culture. At the beginning of the year, Sue talked about what it meant to her to build a supportive classroom culture.

> I made a decision that I'm not giving up on anybody, and if one way doesn't work, I will try something else. And for some of these children, that's going to take a little more convincing, because even though they've only been in school three years, they've already developed the idea that they can't do something. And I think if I target those children, and

> give them opportunities to share, and give the other children opportunities to applaud them, then they will start to think that they can do things that maybe they just didn't think they could do before. (Interview, 8-14-03, Line 155)

She gave examples of two students that she supported. First, she talked about how she supported a boy who said he never learned anything in school. "He was grumpy and unhappy and he hated school. And just by being able to pull back some things that I had heard about him, I could focus him, and he was fine" (Interview, 8-14-03, Line 160). Then she described another situation where a student was not doing his work because he didn't know where to start. "I said, "Tell you what. I'm going to put a '1' a '2' and a '3'. Do the '1' first, the '2' , then the '3'. And he finished" (Interview, 8-14-03, Line 175). So, to Sue, the key to supporting these students was in not arguing with them or walking away from them, as she had done in the past. But, rather she showed them that she cared about them by being patient with them, and recognizing them.

Sue expressed the impact of her providing a supportive environment for her students.

> Those kids who didn't get a lot of respect in their classroom because they were not considered the star students, I think today they looked like the stars. And I think a lot of children realized, "Hey, they're pretty smart! Look what they did!" And as the kids see me encouraging those children, they'll also encourage one another. I noticed some of that today, even, as they were working together, that it was starting to spill over to them. Which is good, because that gives me some help. I don't have to be the only cheerleader in the room. (Interview, 8-14-03, Line 73).

So, for Sue, building a classroom culture became a community effort – one in which the whole class took part in encouraging and applauding each other.

Lois

Prior Experience

Lois has taught sixth grade mathematics in a large suburb for nine years. Even though she had concerns about her own knowledge of mathematics, she perceived that her colleagues thought of her as being “really smart” because she taught gifted courses and coached the academic bowl team at her school (Interview 6-12-03, Line 35). In addition, Lois considered herself to be moderately experienced with technology, having used it for drawing, graphing, and extensions such as the “Stock Market Game”, and mathematics history presentations. She had even used GSP a couple of times.

> I took them on one of those little tours that you have at the beginning of that GSP book to show them how to use the different buttons. We made these real cute 3d letters, and then made it move with the animation. And they really liked that! But we just wasted our time. (Interview, 6-12-03, Line 62)

Even though Lois’ students really enjoyed anything with the computer, “most of them are very computer savvy” (Interview, 6-12-03, Line 87), she abandoned using GSP because she didn’t feel that she was able to use it in a productive way. She indicated that her middle school had many mathematics software programs available, both in her classroom and in three computer labs. (Pre-Survey).

Mathematics. Lois viewed mathematics as a destination kind of subject (Interview, 6-12-03, Line 265). By that she meant that mathematics was about finding answers. “I’ve always thought that the thing that was so neat about math is you have one answer” (Interview, 6-12-03, Line 260). And in her experience, mathematics problems typically involved very few steps. “I’m not used to having to do a lot of different steps to solve a math problem" (Interview, 6-12-03, Line 250).

In addition, Lois firmly believed that mathematics is a "use it or lose it" subject (Pre-Survey; Journal 6-02-03). She clarified that she remembered the mathematics she used in her teaching and coaching; but, had forgotten much of the mathematics she learned in high school and college. For the last year, she had been considering taking a mathematics course, but feared she would not be successful because of her rusty mathematical knowledge (Interview, 6-12-03, Line 25).

Mathematics teaching. Lois described herself as an enthusiastic teacher claiming that she felt obligated to "make math fun" for her students (Interview, 6-12-03, Line 270) so that her students will remember her class forever (Interview, 6-12-03, Line 326). However, she admitted that sometimes she just had to give students the "boring nuts and bolts" (Interview, 3-4-04, Line 40). Her rationale for this was the quicker she got through the school system's requirements, the more time she could spend on other more exciting things. So, to Lois, mathematics teaching involved enthusiastically providing students with the basic information that they needed to know. In addition, because Lois taught gifted students, she claimed that her mathematics classes had to be different than regular mathematics classes. So, after students learned the basic information from a unit, she typically provided them with application projects dealing with topics like roller coasters and boxcars. She claimed that these were "so much fun, and the kids just loved doing them" (Interview, 6-12-03, Line 198). She added that geometry is her favorite strand to teach because "it is so hands-on and concrete" (Pre-Survey) and there are so many projects, like building 3d models of polyhedra using straws (Interview, 3-04-04, Line 37).

Even with the application projects, Lois expressed concern about some of her prior students who she felt unsuccessful with being able to intellectually challenge because they already knew the entire sixth grade curriculum (Interview, 6-12-03, Line 387). So, prior to the institute, Sue had a desire to make her mathematics teaching more interesting and challenging for students.

Mathematics learning. Lois identified that people are either "kinesthetic, visual, or oral learners" and believed that most people are kinesthetic learners (Interview, 6-12-03, Line 75). To her that meant that mathematics is learned through hands-on experiences. An example she gave of how she introduced mathematics content with hands-on activities was that when teaching volume or area, she typically lets students manipulate cubes so they can understand what a unit is.

Within this orientation, Lois identified two schools of thought about how mathematics is learned: by mindless drill and practice or meaningful memorization. Because she claimed that she's not a "big drill person" (Interview, 6-12-03, Line 291), she tried to make information in her lectures tangible or cute to make content easier for students to memorize. She added:

> It's not going to hurt them to memorize the basic facts that they need to know. And especially with kids that I teach, a lot of times they've never had to study. And the simple exercise of studying to memorize is very good for them, because they are going to have to study. (Interview, 3-03-04, Line 88)

Once students had memorized the content, she believed that they should only have to practice enough to check for accuracy.

Summer Institute Experience

Lois registered for the institute for staff development credit. She claimed that she was not aware prior to arriving at the institute that it was a mathematics course. Rather, she thought she would be getting some fun geometry projects to use with her gifted students (Journal, 6-02-03). Lois described her experience at the institute as different from most professional development opportunities that she had attended in the past because she actually had to think. “Usually I am totally spoon fed, and I like it!” (Interview, 6-12-03, Line 8). But at the institute, Lois claimed that she was intellectually challenged for the first time in a long time (Interview, 6-12-03, Line 26).

On the other hand, Lois didn’t feel successful at the institute because there were others that she perceived knew more about mathematics, constructions, and proofs than her. “I felt stupid. I was never made to feel stupid by anybody. If we had a problem they were there, and they were nice. It was only my own lack of self-confidence” (Interview, 6-12-03, Line 243). Because Lois was not fresh on the material that was used at the institute, she felt that she would have been more successful if she had had a day of “hard-core review” about geometry definitions and theorems (Interview, 6-12-03, Line 132). So, to Lois, the institute was a different kind of professional development – one in which she felt intellectually challenged, treated nicely, and unsuccessful (Post-Survey).

Mathematics. During the institute, Lois’ definition of mathematics as a destination was challenged. She began to view mathematics as more than getting answers, but also including processes. She identified an investigation where she divided a line segment into thirds (and other equal sized parts) as contributing to her change. “There were all these different steps that had to be done. I think that was just so much fun! And I did it different ways.” (Interview, 6-12-03, Line 248). Thus, the institute challenged Lois' definition of mathematics as a destination. Instead of just finding answers, she began to value multiple steps paths through investigations.

Mathematics teaching. During the institute, Lois thought about ways she could better teach gifted mathematics. Mainly, she began to recognize that even though she does extra things beyond the basic curriculum with her gifted students, that it may not be as high of a level of learning as they need. (Interview, 6-12-03, Line 345). She pointed at her experience with being intellectually challenged as contributing to this change. She claimed that she identified with her students, especially those who are never satisfied with just memorizing mathematics (Interview, 6-12-03, Line 359). So, rather than thinking about gifted teaching as providing fun application projects after learning the basic facts, she began to value finding ways to really intellectually challenge her students.

Mathematics learning. During the institute, Lois modified her understanding of how gifted students learn mathematics. She began to recognize that people learn in different ways, including through verbalization and visualization. With respect to verbalization, Lois claimed that her experience of having to listen to [the professor] for long periods of time made her concerned about how much she talked in her own classroom (Interview, 3-03-04, Line 50). Because she did not enjoy the lecture time, "my eyes glaze over during lectures" (Journal 6-04-03), she began to consider the role of dialogue in learning mathematics.

With respect to visualization, Lois pointed at her becoming more familiar with GSP and its capabilities as contributing to this change. "I'm much more secure [with GSP] than I was beforehand" (Interview, 6-12-03, Line 77) and "it gave me some inspiration to actually use GSP in a meaningful manner (6-12-03, Line 43). She pointed at an experience with constructing an equilateral triangle using GSP that was particularly significant to her change. The professor had requested input from the group on how to construct an equilateral triangle. Lois offered a suggestion to use the measurement tool. The professor rejected this idea, accepting another participant's suggestion to use circles. Later Lois reflected back on this:

> When we talked about how you create an equilateral triangle. I wondered "Why did he draw that circle there? What is the purpose of that circle?" I didn't feel like I had all the tools I needed to be able to do what I needed to do. And then today, I thought, "Oh, ding, ding!" (Interview, 6-12-03, Line 134).

Lois added that she "didn't know if [she] would have ever remembered to use a circle" (Journal, 6-02-03). But, by using GSP to visualize the construction, she was able to figure it out on her own, without remembering or being reminded.

Intended Classroom Experience

In the fall, Lois would begin her tenth year of teaching sixth grade gifted mathematics, returning to the same school she had taught at in the past. Since she had struggled with many of the investigations at the institute, she expressed some concern about thinking of activities that would be age appropriate for her gifted sixth grade students (Journal, 6-03-03). In addition, Lois claimed that the institute made her more sensitive to giving her students the information that they needed to be successful. "I don't want to just spoon feed them, but it made me a whole lot more sympathetic for my students. Now I'll make sure I've given them all the raw material that they need to have" (Interview, 6-12-03, Line 17). On the other hand, she also expressed the importance of how she was treated at the institute.

> It was such a positive experience that I hope will carry over when I'm with my kids. I hope if a kid doesn't understand something, that I don't think to myself: "For crying out loud, I've taught this three times now!" Just in the interaction, I felt that I will remember

> how I felt when I was so frustrated and upset. I will treat my children with as much respect that I was treated by all these people. (Interview, 6-12-03, Line 236).

Recognizing that she wasn't sure how (Interview, 6-12-03, Line 316), her intentions for her classroom included: incorporating investigations, intellectually challenging her students, and using GSP.

Incorporating investigations. Lois claimed that in the fall, she wanted to provide students with more opportunities for focusing on process rather than just on answers. I guess I want to get them past the point where I was, that math involves more than just getting one answer and that there's different ways to do it (Interview, 6-12-03, Line 276). She felt that the types of investigations, although beyond her normal expectations for sixth graders, were well-suited for gifted students (Journal, 6-02-04). Rather than adapting the institute's investigations, she hoped to be able to incorporate a more exploratory approach, where students do more on their own, into the application projects she already used (Interview, 6-12-03, Line 378). She described how this might look: "I've though about maybe you own a company where they would have to design their own prototype of an oatmeal carton body with toilet paper legs. And figure out the cost of production" (Interview, 9-03-03, Line 129). So, Lois' intentions for incorporating investigations were to modify her existing projects to be more focused on multiple steps and ways of thinking, rather than an end results.

Intellectually challenging students. Lois stated that in the fall, she wanted to do a better job of intellectually challenging her students. "I can be extremely evil now and then, because it's going to freak some of them out to make them actually really think hard" (Interview, 6-12-03, Line 274). So, because she had been intellectually challenged, she began to value this for her gifted students. Lois clarified that she would continue doing units like the roller coaster unit because the kids love it, but questioned what they were getting out of it.

> I just don't want math to be, "Oh, well, gifted math is so cool because we play the stock market game, and we did the roller coaster unit." You know. I want them to really feel like they are really being intellectually challenged. (Interview, 6-12-03, Line 202).

So, Lois' intentions for intellectually challenging students were to make students think at a higher level than the basic lessons and application projects she usually gave them.

Using GSP. In the fall, Lois intended to incorporate GSP into her teaching. Specifically, she planned to use GSP after students were comfortable with geometry (Journal, 6-02-03). She described how she intended for this to look in her classroom: "I'll explain to my kids how to understand that a radius truly is exactly the same distance from the center to any point on the circle. Especially when we talk about how to create an equilateral triangle" (Interview, 6-12-03, Line 81). So, because Lois had learned how to construct an equilateral triangle using the radius of a circle, she wanted to tell her students about this. She added that her new security in how to use the software helped her to understand how it could be used more meaningfully than she had been able to in the past.

Actual Classroom Experience

Lois began the school year teaching sixth grade gifted mathematics. Prior to returning to school, she sustained an injury that progressively deteriorated, eventually requiring several surgeries. Lois claimed that at the beginning of the year, she was in so much pain that she was unable to focus on anything except making it through the day.

> My classroom is not as good as I need for it to be right now because it's really hard to be a good teacher when you have to sit down most of the time. I can not believe how I don't care about anything but just the day to day. (Interview, 9-03-03, Interview, Line 8)

She recognized that her intentions to incorporate investigations, challenge students, and use GSP were still important.

> I'm disappointed that I have not been able to do more. I think it will be fun when I get to that point where I can use what I learned. And I probably will tend to try and do more when we get to the geometry unit (Interview, 9-03-03, Line 121).

So, because of her health, Lois postponed making sense of her professional development experience until her geometry unit.

When Lois returned to her classroom in March, after being out for several months, she began her geometry unit. However, her intentions had been modified. For example, her intention to incorporate investigations became "letting students go in any direction they want with a purpose" instead of focusing on the process of multi-steps and paths (Interview, 3-03-04, Line 120). In addition, intellectually challenging students became " talking less and letting students figure out more" (Interview, 3-03-04, Line 49). On the other hand, she abandoned her intention to use GSP claiming that she no longer felt comfortable enough with the program to use it with her students.

> I'm still kind of insecure on GSP. I would like to be able to use it. But, I can't at this point. Maybe within the next year or two that I'll have it down pat. I think GSP is really cool, but it's hard to understand for me. (Interview, 3-03-04, Line 51)

So, Lois' distance from both her professional development and classroom experience caused her to modify and abandon her intentions for her classroom.

Lois claimed that she would not be able to work on her intentions this year and expressed disappointed with herself for not being able to accomplish her goals. “Man, I was going to be like the best dad-gum teacher you’ve ever seen! And I’ve just been so distracted” (Interview, 3-03-04, Line 152). However, she recognized that her experience at the institute had made her aware of things that she can do to better serve her students. “Now I know that there’s other things there that make your lessons better and make them make more sense to the kids. Whether I am able to use them of course, that’s a whole different thing” (Interview, 3-03-04, Line 135). But, she added that she hoped to be able to in the next year or two.

CHAPTER 5

MATHEMATICS TEACHER DEVELOPMENT

In this chapter, I examine the process of mathematics teacher development. The analysis was guided by the following questions: how do teachers make sense of their professional development experiences:

a) from their practice?

b) for their practice?

c) in their practice?

The four components of teacher development offered in Goldsmith and Schifter's model of the development of mathematics teaching – qualitative reorganizations of understanding, orderly progression of stages, transition mechanisms, motivation and disposition – provided a framework for answering these questions.

Making Sense of Professional Development From Practice

Teachers bring to professional development experiences different contexts and understandings from their practice that determine what constitutes opportunities for thought and action in their professional development. As teachers encounter new information and experiences in their professional development contexts, they perceive inconsistencies between their current understandings and the demands of the environment. It is the confrontation and resolution of these perturbations from which new understandings are reorganized, both in terms of deepening and expanding their knowledge of and reexamining their beliefs about mathematics, mathematics teaching, and mathematics learning. This dynamic relationship of how teachers make sense of their professional development experience from their practice is modeled in Figure 1.

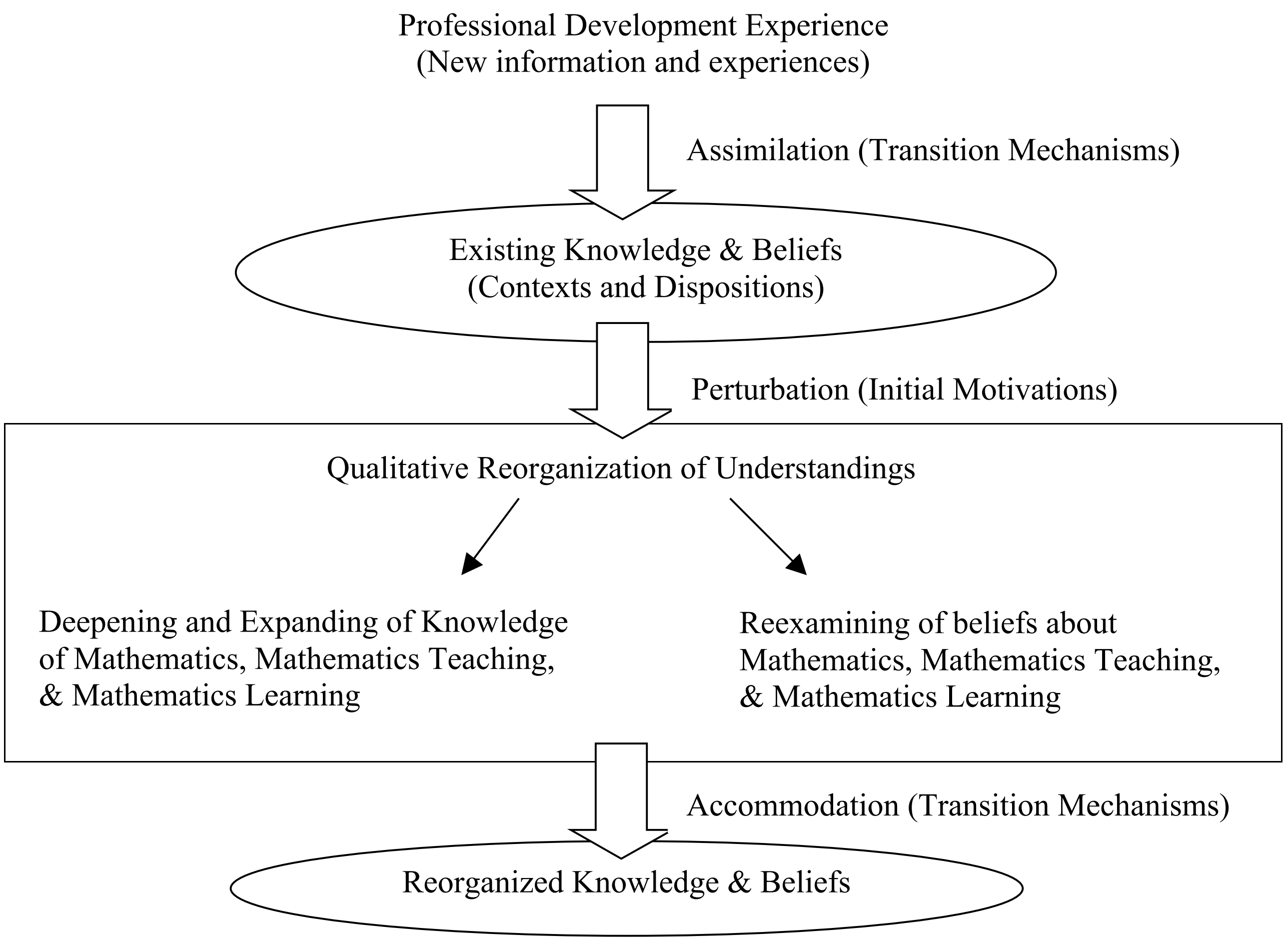

Figure 1. From practice model

Prior to the institute, Mia, Sue, and Lois each held their own set of knowledge and beliefs that formed the basis of their prior practice. In this section, I describe how Mia, Sue, and Lois made sense out of their professional development experience from their practice. I identify their existing knowledge and beliefs (including contexts and understandings), their institute experiences (including transition mechanisms), and their reorganized understandings (including their initial motivations). Each participant's parallel understandings – their reorganized knowledge and beliefs and corresponding preconceptions – are summarized in Tables 1, 2, and 3.

Mia's Process of Development From Practice

Existing knowledge and beliefs. As a graduate student in Instructional Technology and prior mathematics major, Mia came to the institute confident with her background in technology and certain strands of mathematics. Mia was success driven – specifically wanting to know what was expected of her so that she could meet or exceed these expectations. Although Mia defined success differently for different people, this disposition influenced how she approached her developmental goals, and was even a motivation for her attending the institute in the first place. Mia also valued efficiency – she strived to be the first person to answer questions and encouraged students to look for the fastest or shortest methods.

For Mia, mathematics was about becoming efficient in reciting and applying formulas to successfully solve problems. Mia viewed mathematics as a set of rules and procedures to be meaningfully memorized and practiced through real-life applications. Within this orientation, mathematics teaching was about giving clear, comprehensive, and correct information about predetermined topics and then providing the opportunity for students to practice and apply this information. Mathematics learning was about remembering, either through sense making or drill and practice. In either case, learning was seen as the result of information provided to students, and then practiced or applied to solidify understanding.

Prior to the institute, Mia had concerns about her knowledge of geometry and how it was taught. In particular, she viewed geometry as a disconnected strand of mathematics that was not meaningful or applicable and only consisted of memorizing definitions and theorems and practicing these with proofs. Partly, this belief was based on her experience with geometry – one of spatial difficulties, memorization of theorems and definitions, and proofs. Consequently, she focused little on geometry objectives in her teaching.

Institute experience. Mia registered for the institute to find ways to make mathematics, especially geometry, more meaningful for her and her students. At the institute, Mia experienced open-ended geometry applications using technology. She identified a parabola demonstration as being particularly important in deepening her understanding of the parabola, and consequently initiating her development. In this experience, the instructor modeled the construction of a parabola on GSP, making connections between the geometric definitions, algebraic formulas, and visual representations. Although Mia was familiar with all three of the components of this demonstration, this was a new experience for her because it connected them together. This was powerful to her understanding of the concept of the parabola, both deepening her understandings of each component and how they were related. The inconsistency between her prior isolated view of the parabola and the new connected one further challenged her views about mathematics teaching. Mia attributed this parabola lesson as the stimulus for her making connections between algebra, geometry, and real-life phenomena. Therefore, this demonstration was an important psychological mechanism for Mia's development.

In addition, Mia pointed at her own observation and use of technology for exploration at the institute as stimulating her development. Specifically, she claimed that by taking away her spatial and artistic disabilities, geometric concepts became more accessible to her. In turn, she began to value making geometry more accessible to her students by visualization and exploration, especially through technology. Thus, by challenging her own view of mathematics learning, her use of technology was a transition mechanism.

Reorganized knowledge and beliefs. Mia's initial motivation for development was her discomfort with her new school, curriculum, and geometry background. First, Mia came to the institute aware that she would be moving from a middle school to a high school that fall. The institute's connection with what she perceived to be high school type activities led her to develop in certain ways. Second, the module-based curriculum that she was required to use at the high school was unfamiliar to her, and differed significantly from her usual teaching style. Her perception of similarities between the module program and the institute compelled her to reconstruct her teaching, drawing from her images of the institute, and even contacting the instructor for further ideas. Finally, Mia's self-identified deficiencies in geometry, both in knowledge of content and teaching ability, motivated her development. Specifically, as she visualized and built understanding of particular topics in ways that she had never experienced before, she realized that geometry and its teaching were not beyond her grasp (Interview, 6-18-03, Line 68).

From her experience at the institute, Mia began to think about mathematics as a body of knowledge that can be visualized and investigated, as she had with the parabola. This, in turn, led to a shift away from the notion that mathematics involves becoming efficient at applying procedures or rules for arriving at the correct answer to a problem. Through her mathematical explorations, Mia deepened her understanding of algebra and geometry, finding meaning in the algebraic formulas and geometric definitions that she had memorized. In turn, this new understanding led her to recognize connections between algebra and geometry that she had never experienced before, thus challenging her view of geometry. Her new understanding led her to recognize that in addition to being applicable to other subjects, mathematics is itself connected;

specifically, between the strands of algebra and geometry. Also, she began to see geometry as meaningful in the sense that it supports algebra rather than just being an isolated strand.

Through her experience with open-ended geometry investigations using technology, Mia expanded her view of mathematics teaching to include applications for the strand of geometry, and to include connections between mathematical strands. Also, Mia began to view mathematics teaching as less about telling and more about demonstrating, especially through technology tools. In this new conception of teaching, investigations were for getting to predetermined information. As Mia reconceptualized the learning process, she recast her role as the director of student learning, where learning was seen less as the result of information provided by her to the students, and more as a result of students' active efforts to make things comprehensible for themselves through visualizing and exploring, especially in geometry.

Preconceptions	**Reorganized Knowledge & Beliefs**
Understandings of Mathematics	
Meaningful (through applications)	Meaningful (through connections)
Efficiency & Accuracy	Visualizing and Investigating
Geometry is Memorization	Geometry is What Makes Algebra Work
Understandings of Mathematics Teaching	
Multiple Paths & Applying	Connections within mathematics
Telling & Practicing	Demonstrations (techer led)
Technology (computation)	Technology (visualization tool)
Predetermined Objectives	Open-ended
Understandings of Mathematics Learning	
Applications (excludes geometry)	Applications (includes geometry)
Repetition & Memory Techniques	Visualization and Exploration

Table 1: Mia's Parallel Understandings

Sue's Process of Development From Practice

Existing knowledge and beliefs. As an Elementary Education graduate student, Sue came to the institute confident in her background in elementary level mathematics and mathematics teaching. Sue valued being different – she liked working problems differently, provoking students to look for different paths, and encouraging others to appreciate different ways of doing things. This dispositional factor provided motivation for initiating her development – she enjoyed trying new ideas. In addition, Sue pointed to her own tenacity as a learner. She claimed that this impacted both her professional development and classroom experiences. In her professional development experience, even though she struggled, she continually persisted with her tasks and sought help when necessary. In her classroom experience, it was natural for her to persevere through resistance and barriers. Finally, I've inferred that Sue also possessed a desire to be current pedagogically. This was evident in her continual reference to developmental opportunities that she had taken advantage of. Likely, a reason that she was able to make so much from her experience at the institute.

For Sue, the centerpiece of mathematics was problem solving. Although she had developed a more complex view of problem solving than the standard textbook word problems, her primary focus was on students' various methods for getting answers to problems. Mathematics teaching was about engaging students in mathematics, with an emphasis on hands-on activities and problem solving. Within this orientation, she planned activities using manipulatives, technology, and other tools for students to visualize mathematical objectives. Mathematics learning was about individual activity - students actively involved in building their own knowledge of a specific topic through hands-on lessons conducted by the teacher. Sue brought concerns about her own teaching of geometry and its importance at the elementary level.

In particular, she viewed geometry as “knowing the names of shapes and how to use a ruler” and the teaching of geometry as the transfer of information from teacher to student. Consequently, she spent less time on geometry, partly because she found it less interesting than other strands that she considered to be more problem centered and hands-on.

Institute experience. Sue registered for the institute to find ways to more actively involve her students in learning geometry. At the institute, Sue experienced a learning environment that challenged her to build on her own knowledge. She identified her experience as a student in a learning community where she was in control of selecting her own topics and activities as a transition mechanism. Specifically, she recognized the importance of the support and encouragement she received with her personally defined objectives.

She also identified several investigations that she claimed to have deepened her understanding of mathematical ideas. Sue claimed that, in particular, her investigation of the circle problem challenged her understandings and initiated her development. In this experience, she investigated different ways to divide a circle into equal parts. She found that each new way she attempted involved different mathematical topics, many of which she had never encountered before. In addition to expanding her knowledge of geometry, this experience caused her to reconsider the nature of mathematics. By focusing on the processes and connections in that problem, her notion of problem solving as getting right answers was challenged. She attributed this problem as a stimulus for her development with incorporating open-ended investigations; thus, making this a transition mechanism for her.

Finally, Sue reported her experience as a struggling student as a transition mechanism. At first, she was intimidated by the fact that she was an elementary teacher in a group of middle school teachers. From her perspective, this meant that everyone else knew more about mathematics. She immediately identified with students she had taught that felt that way, and she wanted them to experience the success that she eventually felt at the institute. By challenging her view of how struggling students learn mathematics, her experience as a struggling student promoted her development with structuring a supportive classroom culture, and was a transition mechanism.

Reorganized knowledge and beliefs. Sue's initial motivations for development were her discomfort with her current ways of teaching and treating her students. First, Sue came to the institute with concerns about her teaching of geometry, both in terms of what she taught and how she taught it. The institute's connection with the properties of and connections between shapes through investigations helped her to realize that the teaching of geometry in ways that were consistent with her overarching views of mathematics was possible. Second, Sue considered herself to be the weakest member of the group at the institute. Even so, she was able to feel success, which she attributed to an environment where she was encouraged and respected. Because she was able to be successful, she wanted her students, particularly those struggling students that she was easily frustrated with in the past, to feel successful. Thus, an additional motivation for Sue's undertaking development was her own successful experiences as a learner.

By grappling with mathematical ideas through open-ended investigations at the institute, Sue began to see problem solving as a tool for investigating mathematical processes and connections, rather than solely as the goal itself. In addition to expanding her view of problem solving, as Sue became better acquainted with the properties of shapes, she began to see the importance of going beyond shape naming in geometry to understanding the underlying properties of shapes. Sue‘s view of geometry became more in line with her view of mathematics in general, as being problem centered. At the same time, her view of engaging students expanded to include students' experiencing mathematics as a whole, rather than just participating in preplanned activities. Under this conception, teaching became less about eliciting specific answers or lines of reasoning and more about connecting why and how something works. Sue repositioned herself as an orchestrator, where learning was seen less as the result of closely managed activities, and more as a result of creating opportunities for students to develop their own personally defined ideas about mathematics in a community. Under this conception, student understanding became both the guide and the goal of practice.

Preconceptions	Reorganized Knowledge & Beliefs
Understandings of Mathematics	
Problem Solving (closed-ended)	Problem Solving (open-ended)
Getting Right Answers	Process and Connections
Knowing Names of Shapes	Knowing Properties of Shapes
Understandings of Mathematics Teaching	
Problem Centered (exludes geometry)	Problem Centered (includes geometry)
Hands-on (visualizing with manipulatives)	Hands-on experiencing/connecting)
Technology (static)	Technology (dynamic)
Telling & Defining (geometry)	Students Formulating (prop. & def.)
Understandings of Mathematics Learning	
Individual Activity	Individual Control in a Community
Mastering Subject Matter	Personally Defined Ideas

Table 2: Sue's Parallel Understandings

Lois' Process of Development From Practice

Existing knowledge and beliefs. Lois came to the institute confident in her knowledge of middle school mathematics. Lois had a desire to be really good at whatever she attempted

(Interview, 6-12-03). This was evident in the importance she placed on others perceptions of her – her colleagues thinking of her as smart and her students remembering her for how she teaches mathematics. In addition, this is evident in her fear of attempting anything unless she thought she would be successful in it, including taking mathematics courses to help her be more successful. This dispositional factor played an important role in motivating Lois' development, particularly with respect to her teaching. She considered being pedagogically current an important part of being a successful teacher. By participating in the institute, she became aware of pedagogy that she was not taking advantage of in her own classroom, thus influencing her development.

Lois also claimed that she valued doing things differently (Interview, 3-03-04, Line 154). She clarified that she gets bored if she has to do the same thing over and over. This disposition provided motivation for Lois initiating development – she wanted to find new things to do in her classroom like integrating investigations and technology. This factor was also a motivation for why she attended the institute in the first place, to find new (and different) geometry projects to use with her students.

To Lois, it was important that mathematics be fun, in the sense that it is hands-on and interesting to students. However, Lois brought concerns about her knowledge of mathematics and how to teach gifted students. She viewed mathematics as a destination, and consequently focused little on the process. For Lois, mathematics was about finding answers to problems. For Lois, mathematics teaching was about giving students the basics with an emphasis on making mathematics fun. Within this orientation, Lois planned hands-on activities to introduce the basics and application projects that she thought students would enjoy. Mathematics learning was about memorizing information in meaningful ways. To her, meaningful meant that it was tangible or cute. Practice was mainly for checking understanding.

Institute experience. Lois registered for the institute to find ways to better serve her gifted students; specifically to get fun application projects for supplementing her geometry curriculum. At the institute, Lois experienced challenging investigations using technology. She identified an investigation where she trisected a line segment in two different ways as contributing to her development. Lois claimed that her investigation of the line segment trisection promoted her development. In this experience, she figured out two different ways to complete a multi-step task, which she claimed was a new and exciting experience for her. This was powerful to her understanding of mathematics as getting answers, stimulating her to value processes through investigations. In addition, Lois pointed at her own experience as a student in a learning environment where she was intellectually challenged and supported initiated her development. Specifically, she claimed that because gifted mathematics classes had to be different than regular mathematics courses, she began to value intellectually challenging students as a means for accomplishing this. So, by challenging her views of what gifted students should do in the classroom, her development was stimulated. Thus, her experience as a struggling student was a transition mechanism. Finally, Lois' use of technology at the institute stimulated her development. Specifically, she claimed that by becoming more familiar with the capabilities of GSP, she could figure out how to use it more meaningfully in her practice. Coupled with her prior students' enjoyment and success with using the program, this experience with technology was a transition mechanism.

Reorganized understandings. Lois' initial motivation for development was her discomfort with her current ways of extending her gifted course. Lois came to the institute with concerns about being able to challenge some of her gifted students. Because Lois considered herself to have been intellectually challenged at the institute, she identified with her gifted students. She desired for them to have similar experiences. Thus a motivation for Lois undertaking development was her own experience as a student at the institute. Through her experience at the institute, Lois began to view mathematics less as getting answers, and more about the process. In turn, this new focus led her to recognize the value of investigations with multiple steps and paths. She began to think about mathematics teaching for her gifted students as being more intellectually challenging. Under this conception, students would be more responsible for thinking things out, rather than being required to memorize the basic facts and then complete projects that applied the content to fun contexts. Lois began to reposition her thinking about the learning process, especially for gifted students, to include more student visualization and verbalization of mathematics. Because she experienced GSP in ways she had not realized were possible before, she began to value it as a tool for helping students visualize, and thus learn mathematics.

Preconceptions	**Reorganized Knowledge & Beliefs**
Understandings of Mathematics	
Finding Answers	Investigations (multiple steps and paths)
Understandings of Mathematics Teaching	
Basics/Projects	Intellectual Challenge
Understandings of Mathematics Learning	
Kinesthetic (hands-on activities)	Visual (GSP)
Lecture	Dialogue

Table 3: Lois' Parallel Understandings

Making Sense of Professional Development For Practice

Within any given professional development experience, teachers construct differing meanings for their practice. As they reorganize their understandings, their new notions contradict aspects of their prior practice. These inconsistent elements, or concerns with practice, form the basis for their intended changes in their future practice. In envisioning new consistent elements for practice, teachers frame the boundaries of what they intend to work on, and project the means for achieving them, leading to some uncertainty in how their intentions will be accomplished in their particular contexts. This dynamic relationship of how teachers make sense of their professional development experience for their practice is modeled in Figure 2.

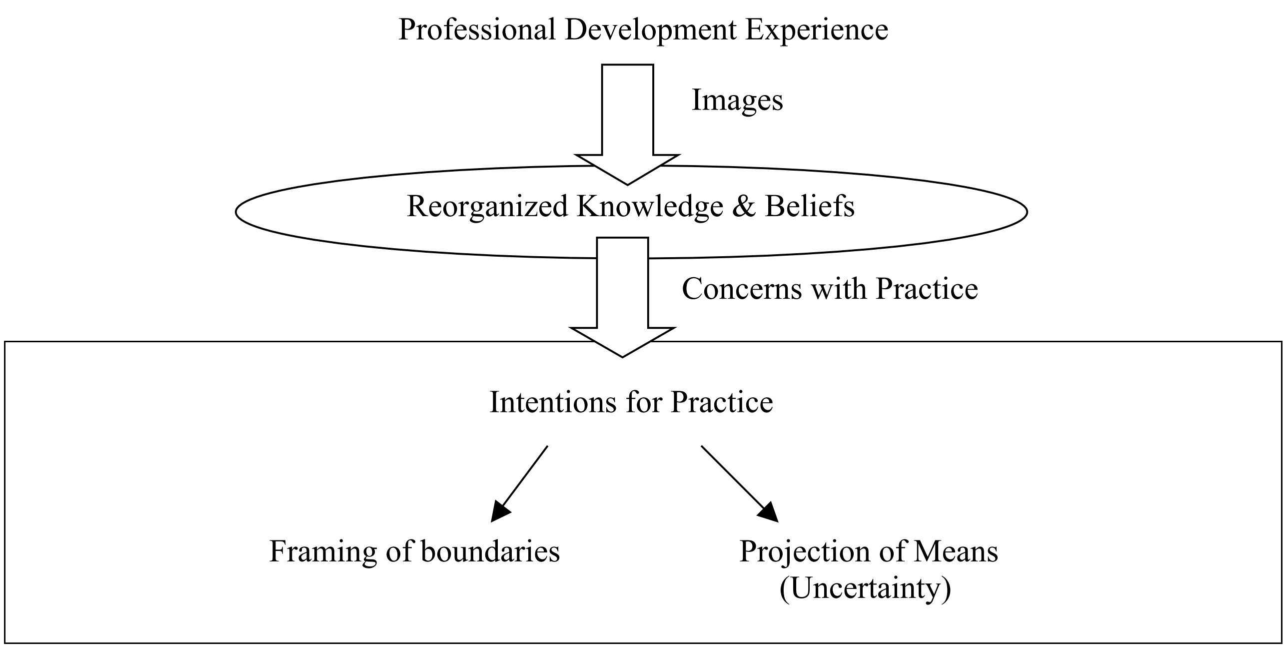

Figure 2. For practice Model

From their participation in the institute, Mia, Sue, and Lois showed evidence of qualitative reorganizations of understandings of mathematics, mathematics teaching, and mathematics learning. In this section, I describe how Mia, Sue, and Lois made sense out of their professional development experiences for their practice. I identify aspects of each participant's process of making sense of their new understandings for their practice: images from their professional development experience and intentions for their practice (including concerns, boundaries, and means) for making sense of thier new understandings for their practice.

Mia's Process of Development For Practice

Images. Mia claimed to have developed many useful images from her institute experience. For one thing, because she was teaching high school (for the first time), she perceived that the level of many of the institute activities were appropriate for her students. Therefore, she immediately saw connections between her own investigations and ones she might do with her students. This was particularly evident in the parabola demonstration – an important topic in both the algebra and geometry courses Mia would be teaching. In addition, the module-based instruction that her new school required was different than her usual type of instruction. She claimed that she modeled her classroom after many aspects of the institute, mirroring the classroom environment of minimal instruction, individual work, and teacher monitoring.

Intentions. Mia's reorganized understandings led her to question her practice, specifically with respect to making connections, using investigations, and using technology. Her development continued as she began to reformulate her new notions into intentions for her practice. First, from making her own connections between algebra, geometry, and real-life situations, Mia wanted to give these connections to her students. With the exception of the connections she had experienced at the institute, like the parabola, Mia was uncertain about her ability to see connections and about how this intention would play out in the context of a new school and curriculum. In addition, by valuing investigations and technology in her own learning process, Mia wanted to incorporate investigations and technology into her teaching. Because she was teaching high school (for the first time), she perceived that the level of many of the institute activities were appropriate for her students. Therefore, she immediately saw connections between her own investigations and ones she might do with her students. This was particularly evident in the parabola demonstration – an important topic in both the algebra and geometry courses Mia would be teaching. She clarified that she would not be using open-ended investigations, or letting students explore, but rather she would demonstrate particular concepts for the class. She claimed this modification in how she used investigations at the institute and how she would use them with her students was due to her concern about time and getting to all of the course objectives. On the other hand, because Mia was comfortable with the technology, having even used it in the past with her students, her concerns were less about her own abilities and more about her new school environment – what technology was available and how it would fit into the curriculum. Even though she had used technology in the past, her intentions were to increase her use of it and to use it for different purposes, mainly demonstration and exploration rather than the static environment she had used in the past.

Sue's Process of Development For Practice

Sue began to think differently about mathematics problem solving, the environment of the mathematics classroom, and the role of support in learning mathematics. Her development continued as she began to reformulate these new notions into intentions for her practice. First, from experiencing open-ended problem solving investigations, such as the circle problem, Sue wanted to modify her focus on problem solving in practice to be less about getting answers and more about the processes and connections. Specifically, she wanted students to formulate their own properties and definitions the way that she had at the institute. Sue identified her work with parallelogram and circle properties as being both empowering to her as a learner and useful images for her practice. Even though she did not feel that the institute activities and content were applicable for elementary age students, she wanted her students to experience the properties of shapes in the way she had at the institute.

In addition, Sue connected with the images of the course structure – the way teachers were treated and the environments that were created. For one thing, Sue recognized the importance of how she was treated at the institute on her development. Because she saw a connection between the patience and encouragement that she received and her success, she wanted to treat her students that way. In addition, Sue identified the importance of the environment at the institute, one in which she was a mathematics learner with personally defined learning objectives. Because this environment where she was respected was empowering for her as an adult, she wanted to create that culture in her classroom. By recognizing the role of the institute's environment and support in her own learning process, Sue wanted to build a classroom community dedicated to learning with a supportive classroom culture as she had experiences. She clarified that this meant encouraging students in taking control of learning personally defined ideas in a community. Whereas in the past Sue got frustrated with struggling students, she wanted to provide patience, persistence, and variety to students to take control of their learning in groups.

Lois' Process of Development For Practice

Lois began to think differently about the goal of mathematics problems, the types of tasks in a gifted mathematics classroom, and the role of visualizing in mathematics learning. Her development continued as she began to reformulate her new notions into intentions for her practice. First, from experiencing multi-stepped investigations at the institute, Lois wanted to modify her teaching to be less about getting answers and more about processes. However, Lois felt that the investigations at the institute were not an appropriate level for her students, so she expressed some uncertainty of how she would accomplish this. She projected that she would probably modify some of her existing projects so that students had to do more exploration on their own, thus having them focus more on process and less on product.

In addition, by valuing her own intellectual challenge, Lois wanted to intellectually challenge her gifted students. Because she was teaching gifted mathematics, she perceived that the types of activities, although not at the same level, were appropriate for her students. Therefore, she immediately saw a connection between her own investigations and ones she might do with her students. This was particularly evident with the equilateral triangle construction, a sixth grade geometry objective. She began to question what students were getting out of the application projects, she planned to modify them to make students think at a higher level. She clarified that to avoid student frustration, as she had experienced at the institute, she would be sure to give them all of the information that they needed. But, she wanted them to think at higher levels than she had required in the past. Lois connected with the course structure – the way she was treated at the institute. Mainly, because she appreciated the patience and encouragement she received at the institute, she wanted to treat her students that way.

Finally, by recognizing the role of visualization in her own learning process, Lois wanted to use GSP in her classroom to help students better visualize geometric concepts. Because she better understood how GSP could be used meaningfully, added to her prior students' enjoyment and success with the program, she was confident that she would use it in her classroom. She clarified that she would use GSP after students were comfortable with the basics of geometry. She claimed that this modification in how she would used GSP with her students from how she used it at the institute was due to her students age.

Making Sense of Professional Development In Practice

When teachers return to their classrooms from a professional development experience, their particular contexts and understandings determine what constitutes opportunities for thought and action in their practice. As they interact within their school and classroom contexts, they encounter a continuous interplay between their current understandings and their practice. At first, teachers hold a new set of intentions that contradict many of the classroom structures and activities that were based on their old understandings. In order to resolve inconsistencies between their new intentions and their practice, they enter a cycle of goal setting, action, and reflection. More specifically, teachers select particular goals for moving toward their intentions, which they apply to their particular classroom context and then reflect on the consequences of their actions, causing further goal setting. Through this cycle, teachers sort out elements of their practice that fail to support their intentions and sort out elements of their intentions that fail to be supported by their practice. Over time, they meet some intentions, modify some intentions, abandon some intentions, and create new intentions. Eventually, participants reach a state of equilibrium as they are able to design and conduct classroom structures and activities that fit their new vision of practice, one based on an reflexive relationship between professional development and practice. This dynamic relationship of how teachers make sense of their professional development experience in their practice is modeled in Figure 3.

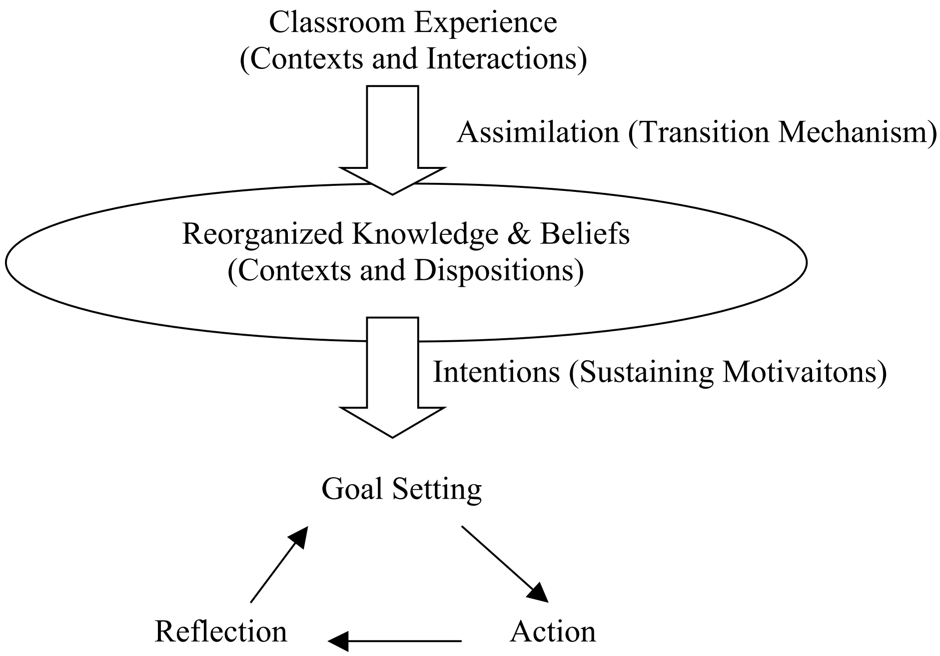

Figure 3: In practice model

After the institute, Mia, Sue, and Lois used their particular school and classroom contexts to reconsider the nature of classroom activities and structures. Their thinking about mathematics, mathematics teaching, and mathematics learning further developed as they refined and organized the teacher and learner roles and responsibilities in the learning process in the context of their practice. In this section, I describe how Mia, Sue, and Lois made sense out of their professional development experiences in their practice. In particular, I identify each participant's cycles of goal setting, action, and reflection in practice, their transition mechanisms, and their sustaining motivations.

Mia's Process of Development In Practice

Goal setting, action, and reflection in practice. Mia focused on the following intentions: making connections, incorporating investigations, and using technology. To make sense of her first intention, making connections, Mia first put into action familiar practices, giving her algebra students applications. Even when teaching the algebraic equation of the parabola, the specific topic she had intended to connect with the geometric definition, and visual representation, she was unable to realize her intention. But, when teaching geometry, she began connecting formulas and definitions, such as the distance formula and the definition of a circle. She claimed that this strand specific transfer of her intention was due to her comfort with algebra and unfamiliarity with geometry. In other words, she was able to find connections with algebra in her geometry course because she was comfortable enough with the algebra content that when she was teaching a geometry topic, she was able to see how algebra related. However, her unfamiliarity with geometry caused her difficulties in seeing geometry in the algebra and discomfort with trying to make even obvious connections.

To make sense of her second and third intentions, incorporating investigations and technology, Mia selected to only attempt implementation with her advanced classes, claiming that her other courses had too many objectives and students that weren't interested in wasting effort by experimenting. With her advanced geometry students, on the other hand, she claimed that her students were patient, eager to experiment, and not afraid to fail. So, Mia began the geometry course (in January) with a demonstration investigation of the Pythagorean Theorem and the distance formula. Students' overwhelming success and positive response with this experience encouraged her to continue. She eventually set up time in the computer lab for students to investigate on their own, even open-ended problems on occasion, encouraging students to go beyond the intended objectives of the lesson. Earlier in the year, this was hard to manage because of her uncertainty of computer time; but, after the first semester, she became comfortable with her colleagues and was able to work around this barrier.

Transition mechanisms. Mia's interactions with students served as both facilitators and shapers of her development – promoting her experimentation with her intentions and creation of new ones altogether. Specifically, she claimed that while her interactions with her advanced students, who were both receptive to and successful with the kinds of activities she had intended, supported her development, her interactions with other students discouraged it. Then because of her success with demonstrating investigations, she began to experiment with the boundaries she had set, giving students more control in the process and opening up the tasks. Students' continued excitement about these activities, as well as discovery of topics that had yet been introduced, or may not have even been course objectives, further promoted her development in this area.

Mia's orientation toward efficiency was particularly evident in her development with her constant focus on time constraints, which was a perceived barrier to many of Mia's developmental goals. On the other hand, when Mia found that students were meeting additional objectives than she had expected, this efficiency disposition promoted her development. Specifically, Mia claimed that her interactions with students about undefined terms promoted her rethinking of the use of open-ended investigations with her students. From this experience, she realized that her advanced geometry students had a considerable amount of intuitive understanding and motivation that she was not capitalizing on. This challenged her previous notions about ninth grade students, and thus instigated further development.

Although Mia did not report her explorations of open-ended investigations at the institute as a stimulus of her development, there is evidence of this mechanism. At first, although she enjoyed open-ended investigations, Mia claimed that she would never use this in her classroom. However, in the classroom, Mia ended up unintentionally allowing this experience to promote her development. There is not evidence of any particular open-ended investigation that was the mechanism; just that it did serve as a mechanism for transition by being an unintentional stimulus for her valuing of investigations.

Mia claimed that at the beginning of the school year, her lack of interaction with colleagues was a barrier to her development. Although she did not specifically indicate any collegial relationships that fostered her development, becoming enculturated into the school and comfortable with her colleagues did facilitate her being able to reorganize her practice. For example, she modified her approach to the modules and scheduled computer lab time.

In addition, the module-based instruction that her new school required was different than her usual type of instruction. Even though Mia claimed that the module-based curriculum hindered her development, there is evidence that it actually was a transition mechanism. Mainly, the new curriculum forced Mia to reorganize her practice around principles that she did not know how to make sense of. This demand of the environment caused her to grasp for resources to operate with, resulting in unintended connections with the institute. Even though Mia was not eager to develop in this manner, this experience was a mechanism for her development. She claimed that she modeled her classroom after many aspects of the institute, mirroring the classroom environment of minimal instruction, individual work, and teacher monitoring. She even contacted the professor to find out more about how he had structured the environment.

Sustaining motivations. Mia claimed that her development was put on hold because she was too overwhelmed with the demands of a new school and curriculum. However, even given this beginning, she held onto her intentions looking for ways to eventually move forward. For Mia, there were a couple of sustaining motivations for development. First, she realized that her existing methods were not adequately serving her students. For her average students, she found that they were not being successful with algebra. Even though they were passing the module tests as required by the curriculum, they were not retaining their knowledge. For her advanced students, on the other hand, she felt they were not reaching their potential. Second, as Mia worked on developing towards her intentions, she met success – both with students' positive response to changes and their learning of required and additional objectives, often prior to their introductory lessons. Third, the network of colleagues Mia built sustained her development. Even though she did not recognize any particular interactions as being important, her comfort with sharing her successes and failures and asking for resources seemed to enable her development.

Sue's Process of Development In Practice

Goal setting, action, and reflection in practice. Sue focused on three overarching intentions: incorporating open-ended problems, building a classroom community dedicated to learning, and structuring a supportive classroom culture. To make sense of her first intention, incorporating open-ended problems, Sue first put into action familiar practices with a twist - providing students with closed-ended problems but focusing less on getting answers and more on process and connections. Even this goal went unmet by students at first. Although disappointed, Sue's tenacity as a teacher encouraged her to adapt her goals to the next classroom experience. As she persisted, students began to successfully offer multiple ways to work problems. After students became accustomed to focusing on process and connections, Sue was experimenting with the nine's problem, and once again experienced disappointment when students were unable to come up with what she wanted them to. However, at the same time, students' unexpected responses, things Sue had never realized, motivated her to modify her goals to include more open-ended investigations, first as planned projects and later as a more integral part of the daily activities. In addition, she met some difficulties in her attempt to modify her geometry teaching to be more open-ended. For example, in teaching the properties of triangles, she found an important part of their investigations to deal with shearing and transforming the triangles. She planned activities for students to understand that the properties of these new shapes were still triangles. When she got to squares, some students were able to distinguish the properties of these new transformed quadrilaterals that removed them from the set of squares. However, others could only recognize that they were no longer squares. This caused her to question how much of this type of knowledge was important for different students to know.

To make sense of her second intention, building a classroom community dedicated to learning, Sue's initial goal was to plan a few experiences beyond the regular classroom activities. However, she faced many struggles with this task. Even though there is evidence of holes in Sue's knowledge (i.e., she defined rectangle as two long and two short sides), she was confident in her knowledge for teaching second grade. However, her perception changed as she came face to face with new ideas offered by her students. In addition, she had trouble with relinquishing control, a major part of her role for the last fourteen years, and having students accept this role, one that they weren't used to having. As she experienced success with this goal, she began to make this intention more of a daily classroom structures – giving students control of the learning environment and having them work together for almost all activities.

To make sense of her third intention, structuring a supportive classroom culture, Sue selected to work mainly with her struggling students, claiming that the successful students are easily motivated. So, her goal was to target students that needed support, and provide the encouragement and patience that they needed to be successful. Sue found that as she began to work on this goal, other students began to take part in encouraging and applauding these students; thus helping her reach both her intention of supporting students and building a community.

Transition mechanisms. Sue claimed that the nine problem promoted her development. She had intended this problem to be an opportunity for students to have control of coming up with a particular relationship. However, while she prompted students for this predetermined relationship, they offered many others that she had not thought of. This experience instigated growth by helping Sue to see open-ended problems as more of a daily reality of the classroom, rather than just planned activities. Thus, this classroom activity was a transition mechanism for her development.

Although Sue did not report the “square properties” investigation as a transition mechanism, there is evidence that it helped her to bound her thinking about her intention to create a supportive classroom culture. At first, because she had been successful at the institute, Sue claimed that through patience, persistence, and variety she would convince students that they could be successful at anything. However, in this investigation, she began to question what success meant for different students – understanding why a shape is a square, or just that it is one. Therefore, this classroom experience was a transition mechanism for Sue’s development of incorporating open-ended problems.

Sustaining motivations. Sue claimed that she started working on her goals the first day of school; although she met some resistance and barriers. First, her school had many other goals for her – vocabulary walls, multiple assessment, and book work. Second, her initial attempts to provoke different ways that students thought about tasks were not productive. Later, her attempts led students to question themselves, sometimes changing their answers strictly because she had requested their dialogue. Third, she claimed that she struggled giving students control, particularly in not telling them what she wanted them to know. Fourth, she feared that she didn't know enough mathematics to correctly answer students' questions generated by teaching in ways more consistent with her new intentions.

Sue claimed that sustaining development during these times was not difficult because her efforts rarely took long to produce desirable results. First, she found that the school's requirements did not require much of an additional investment in her time. Second, she found that students quickly learned that it was her style to discuss everything. Eventually, students began to offer their thinking without being prompted and even were discontent with just getting answers to problems. Third, by letting students have more control, she found they were more confident and they ended up learning more and different things than if she had been in control. Fourth, she found that letting students answer their questions using the Internet, dictionary, encyclopedia and other resources alleviated pressure and simultaneously supported her goal of wanting students to take control of their learning. So, Sue's sustaining motivations were the success she felt from students enjoyment of and productivity with the types of activities she enacted. "They learned math and they loved it" (Interview, 8-14-03, Line 227). She even claimed that her students asked daily when they would be doing mathematics and were frequently late for lunch because of their deep involvement in mathematics activities.

Lois' Process of Development In Practice

When Lois returned to her classroom, she had intended to focus on incorporating investigations, intellectually challenging students, and using GSP. However, as she tried to make sense of her intentions in her school and classroom contexts, she found that she was unable to focus on anything new. So, she postponed her developmental goals to later in the year, when she would be teaching geometry.

When Lois returned to school in March, even though she continued to value her intentions, she was disconnected from both her professional development and classroom experiences. This disconnect caused her to modify some of her intentions and abandon others. Because Lois was removed from her classroom, she was not able to take action on her intentions. Therefore, there is not evidence of her entering into a cycle of goal setting, action, and reflection. Also, this study did not identify any transition mechanisms or sustaining motivations for her development. So, I was not able to capture how Lois made sense out of her professional development experience in practice.

CHAPTER 6

SUMMARY AND IMPLICATIONS

The purpose of this study was to understand the process of development that teachers encounter as they construct meaning from their professional development experiences. Constructivism, a theory of meaning-making in which learning occurs when individuals interpret their current experiences in light of their past knowledge, provided a foundation for examining mathematics teacher development. I offered the following definitions based on a constructivist epistemology:

1. *Professional development* is any learning experience where teachers meaningfully interact with their knowledge of and beliefs about content, teaching, and learning. This includes formal learning experiences such as teacher education and staff development, as well as informal learning experiences such as interactions with students and teachers.
2. *Practice* is what teachers do (actions) and their motivations for what they do (intentions) in their classroom experiences. Teachers' actions and intentions are situated in particular contexts and are heavily influenced by their prior experiences and their existing knowledge of and beliefs about content, teaching, and learning.
3. *Teacher development* is the changes in knowledge of and beliefs about content, teaching, and learning that teachers encounter as they make sense out of new information and experiences through the meaningful interaction of new ideas with what they already know and believe.

By viewing mathematics teacher development as knowledge construction, I assumed that teachers develop when they construct meaning from their professional development experiences in the context of their prior, intended, and actual practice. In studying this iterative relationship, data were collected from three practicing teachers during a week-long summer institute and subsequent year of teaching as a means of addressing the following research questions: How do teachers make sense of their professional development experiences:

a) from their practice?

b) for their practice?

c) in their practice?

Research Framework

Goldsmith and Schifter's (1994) model for the development of mathematics teaching provided a research framework from which to view teacher development. This model highlights an iterative perspective in which teacher development involves a continuous interplay between changes in knowledge, beliefs, and practice. Goldsmith and Schifter suggested four components that should be taken into consideration when examining mathematics teacher development from an iterative perspective: qualitative reorganizations of understanding, orderly progression of stages, transition mechanisms, and motivation and disposition. These components of mathematics teacher development models were useful in guiding the design, data collection, and analysis of this study. First, I took qualitative reorganizations of understanding as a basis for this study, defining teacher development in terms of changes in teachers' knowledge and beliefs. Thus, in designing this study, I was concerned with how teachers, who have experienced qualitative reorganizations of understanding, make sense out of their changed notions. This impacted many of the decisions I made. For example, I purposely selected participants from an environment that was likely to provide the opportunity for teachers to reorganize their understandings and I selected participants that showed evidence of qualitative reorganizations.

Second, when collecting data, I looked for: parallel conceptions; global trends of development; mechanisms attributed to transitions; and affective factors initiating, sustaining, and influencing the task of development. Finally, I coded data in terms of its potential to inform me about: preconceptions and reorganized understandings; the orderliness of development; transitional experiences, images, and interactions; and initial motivations, sustaining motivations, and influencing dispositions. What follows is a discussion, organized around the four components of teacher development, of what can be learned about mathematics teacher development from this study followed by a critique of the research framework.

Qualitative Reorganizations of Understanding.

Mia, Sue, and Lois showed evidence of changes in their knowledge and beliefs about mathematics, mathematics teaching, and mathematics learning from their participation in the institute. In this study, I identified their changes or perceived changes in knowledge and beliefs and parallel preconceptions. There are some important observations that can be made about qualitative reorganizations of understanding from these cases. First, although the three participants attended the same institute, they each constructed different understandings from their participation indicating that teachers make sense of professional development opportunities in unique ways. This raises questions about how we think about teacher development. Rather than being a predictable product of pivotal experiences, it is an individual process.

Secondly, teachers' understandings, although not linear, seem to progress from goals to means. For example, Sue's preconception of mathematics as problem solving was about students learning how to solve mathematics problems because to her this was an important life skill. Thus, problem solving was the goal. Under her new conception, mathematics as problem solving became a means for investigating mathematical structures and connections, rather than an end in itself. Likewise, Lois' concept of mathematics teaching changed from learning the basics and then applying it through projects to including more intellectual challenge. So, rather than viewing projects as a goal for her teaching (to satisfy the extra requirements of teaching gifted students), she began to see it as a means for challenging her gifted students. A final example is that Mia's concept of mathematics teaching changed from learning through applications, where applications were the goal, to include applications as a means for making connections within mathematics. Thus, for these teachers, their initial goals became means for reaching more complex goals.

Qualitative reorganizations of understanding are important components of mathematics teacher development and should be taken as a basis for models of mathematics teacher development. However, there is still much to learn about how qualitatively different mental organizations progress over time. Here, I've identified two characteristics from this study that add to our understanding of qualitative reorganizations of understanding.

Orderly Progression of Stages

I've described Mia's and Sue's development from, for, and in practice, identifying orderly progression of stages across participants. These models portray aspects of teacher development that are orderly, pointing out the importance of examining teacher development from, for, and in practice. What follows is a synthesis of some themes of orderly progression of stages that I've identified from this study.

Although Mia, Sue, and Lois attended the same institute, the particular contexts and understandings they brought from their practice determined unique opportunities for development making their professional development experiences quite different. For example, Mia claimed that the parabola demonstration was an important experience for her development because it provoked her to interact with her prior knowledge of the parabola and contributed to her reexamination of her beliefs about learning mathematics through applications. This same demonstration had little impact on Sue and Lois, who claimed that the concepts were beyond their level of understanding. However, Sue and Lois each identified other experiences or environmental factors that caused them to interact with their prior knowledge and beliefs. This indicates that professional development is not entirely about the curriculum because new ideas and experiences impact individuals differently. Rather, professional development is about getting teachers to interact meaningfully with their prior knowledge and beliefs from their practice.

Mia, Sue, and Lois each encountered qualitative reorganizations of their understandings during the institute. These changed notions led them to question the adequacy of their current practices, leading to intended changes for their practice. In some cases, they refined aspects of their practice – Mia refined her concept of using technology, Sue her concept of problem solving, and Lois her thinking about application projects and technology. In other cases, they projected new aspects that they intended to assimilate into their practice. Mia intended to begin making connections between algebra and geometry and using investigations, Sue intended to build a new type of learning environment, and Lois intended to incorporate investigations. With the exception of aspects of their own professional development experience that they planned to replicate or slightly modify, each participant expressed uncertainty about the means for framing their intentions for their particular contexts. Some features of the institute that were instrumental for these participants were particular investigations, the use of demonstrations and technology, and the supportive learning environment. This indicates that teachers' experiences are important aspects of how they make sense of professional development. Thus, professional developers need to be conscious of the tasks, pedagogies, strategies, and environments they provide, because they may become stimuli for change.

As Mia and Sue returned to their classroom environments, they began their development with familiar practices. Mia continued to use applications with her algebra students without making connections to geometry and Sue provided students with closed-ended problem solving situations. As they began to move towards their intentions, they experimented with unfamiliar practices. For both participants, implementation was selective – Sue focused on her struggling students and Mia worked only with her advanced students. Through a cycle of goal setting, action, and reflection, both Mia and Sue looked for positive student learning outcomes which further promoted their development. For Mia, outcomes included students' affective responses and an increase in the quality of their mathematical thinking. In Sue's case, her intended outcomes were not always reached, but her students surprised her with unexpected mathematical thinking, an outcome Sue recognized as positive. This is consistent with Guskey's (1986) temporal perspective where changes in teachers' knowledge and beliefs are spurred by tentative changes in their practice that result in positive student learning outcomes.

Development, however, did not proceed without moments (sometimes even months) of being stuck. Whereas Sue identified times of frustration where she felt unsuccessful with her progress, Mia had an entire semester where she was unable to realize her intentions. Lois', on the other hand, was not able to realize her intentions at all during the time frame of this study. This indicates that the progression of stages is not sequential.

Transition Mechanisms

Mia and Sue (and to some extent Lois) experienced a continuous interplay between their understandings and their practice. These transitions were stimulated by particular experiences (both events and activities) and occurred in both their professional development and classroom contexts. I have identified some of these psychological and sociocultural mechanisms that contributed to their transition from one level of understanding to the next. Transition mechanisms are important elements for professional developers to understand. For those seeking to facilitate teacher development, it would be important to find ways to activate these mechanisms. In this section, I identify some observations about transition mechanisms that will inform professional developers.

First, it is apparent that teachers do not always recognize experiences and images that were significant in stimulating their development. For example, Mia did not recognize open-ended investigations from the institute and Sue did not recognize the "square properties" investigation in her classroom experience as being influential in their development. They did not recognize these aspects of their experience because they did not fit into their existing cognitive structures; however, these experiences did serve as mechanisms for transition by becoming part of their current understandings from which they could draw from in new situations. In addition, since teacher development continues in practice, teachers may only become aware of particular transition mechanisms after returning to their particular classroom contexts. This is apparent in Mia's recognition of mirroring the institute's structure in her module-based classroom.

These characteristics of transition mechanisms have significance for how we assess professional development opportunities. Much of the impact of these opportunities is missed when data rely solely on teachers' self-reports at the conclusion of the experience. Thus, in order to find ways to activate these mechanisms, we need better methods of identifying them in the first place.

Motivation and Disposition

According to Goldsmith and Schifter (1994), little attention has been paid to the affective issues of motivation and disposition in the literature on teacher development. In this study, I have identified some of the motivational and dispositional factors that influenced Mia's, Sue's, and Lois' development. Some common themes have emerged from this analysis about motivational and dispositional factors.

With respect to initiating motivations, first, both Mia and Sue reported concerns that their current practice did not adequately serve some of their students. For example, Mia was concerned about challenging her advanced students while Sue wanted to support her struggling students. Second, participants identified discomfort with their current practice. Mia's discomfort was with her new school environment, an unfamiliar curriculum, and weak geometry background. Sue's discomfort was with the inconsistency in how she taught geometry compared to other strands and how she treated her struggling students. Lois' discomfort was with her current ways of extending her course to meet the needs of her gifted students.

With respect to sustaining motivations, factors that promote the continuation of development may also be barriers. For example, school initiatives, such as Sue's "Learning Focused Schools" or Mia's module-based curriculum, can either encourage or discourage development. For Sue, these initiatives simultaneously promoted her development by focusing her on big goals and distracted her from her intentions by giving her more tasks to focus on. For Mia, these initiatives overwhelmed her, causing her to temporarily replace her developmental goals with others – thus, both promoting and deterring her development. Another example is that although student learning outcomes sustained development for both Mia and Sue, in some cases it also was a barrier. Even within the same environment, some students may have positive learning outcomes while others become frustrated or have no response at all. Likewise, it is important to note that for different teachers, the same experiences may either serve as motivations, barriers, or even have no impact. These responses may be attributed to the teacher's particular dispositions.

With respect to dispositional factors, even though each participant had unique individual characteristics, some issues emerged. Mia, Sue, and Lois all recognized the importance of success. Teachers wanted learning, for both themselves and their students, to be without frustration. This is an important issue because teacher development is not a smooth journey to success. Other characteristics such as persistence, courage, and the desire to be different played an important role in these teachers' development. More needs to be learned about how to encourage teachers to find compelling reasons to initiate and sustain development and how individual dispositions influence that development.

Critique of the Research Framework

Goldsmith and Schifter's model was useful for designing and implementing this study of teacher development. Using this model as a research framework, I have described what teacher development looked like for these three participants, offering a conceptualization of how teachers make sense of their professional development experiences from, for, and in their practice. I've provided actual descriptions and data for three teachers of these components, confirming the relevance of these components in looking at teacher development. In addition, I've added to Goldsmith and Schifter's model by taking into account barriers to development, showing the interconnectivity between the components, and challenging their claim of alternate pathways.

The first modification to Goldsmith and Schifter's model from this study addressed barriers to development. Although the model recognizes the mechanisms and motivations as important aspects of development, it does not account for barriers to development. In this study, I included barriers to development with the affective factor of motivations, recognizing that barriers can also serve as motivation for initiating or sustaining development.

A second modification of the framework was related to the interconnectivity between the components. In Goldsmith and Schifter's model, the components of teacher development are treated separately, only mentioning that the interaction between these factors "can help to guide the design and planning of intervention programs that aim to help teachers work to change their practice" (1994, p. 12). This study has taken a step toward this end, offering a conceptualization of teacher development that connects the four components Goldsmith and Schifter's model.

Finally, Goldsmith and Schifter raised the issue of whether or not mathematics teacher development occurs in a stage-like manner. Specifically, they posit that "there are a relatively small number of pathways that teachers take as they seek to change their practice" (1994, p. 8). In this study, I found that teachers' directions of development were not predictable. Rather than looking for alternate pathways, I offered global trends of development that represent the progression of development teachers take regardless of their direction. Thus, a final modification to the framework involved revising the interpretation of what is meant by orderly progression of stages.

The examination of how teachers construct meaning from their professional development experiences in the context of their prior, intended, and actual practice proved to be a viable strategy for understanding mathematics teacher development. I encourage mathematics educators to consider this iterative relationship as a way to think about mathematics teacher development from, for, and in practice.

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APPENDIX A: INTERVIEW GUIDES

First Interview

1. Tell me about your experience at the Summer Institute
    - What about the Summer Institute stands out to you?
    - Why was this experience meaningful to you?
2. Tell me about something you learned this week.
3. [In the survey/During the Institute/In your journal/In this interview] you mentioned ____.
    - Tell me more about this.
    - What led you to mention this?

5. Will this experience affect your practice this fall?
    - How?

Second Interview

1. This summer, you mentioned ____.
    - Tell me more about this.
    - How has your practice influenced how you think about this?
    - Why?
2. I really liked how you ___ in class today (maybe view segment from video tape).
    - Tell me about this.
    - Does this relate to your experience in the Summer Institute?

APPENDIX B: PRE-SURVEY

center for proficiency in teaching mathematics

2003 CPTM Institute
Geometry for Middle School Teachers
Institute Pre-Survey

Name:	District/School:
Phone (for contact during summer):	E-mail (for contact during summer):
Number of years teaching mathematics:	
Do you have middle school mathematics concentration? Yes ☐ No ☐	

How much experience have you had working with (check all that apply);	none	little	moderate	extensive
Excel	☐	☐	☐	☐
FETCH (FTP)	☐	☐	☐	☐
Geometer's Sketchpad	☐	☐	☐	☐
Graphing Calculator 3.0/NuCalc	☐	☐	☐	☐
Microsoft Word	☐	☐	☐	☐
Netscape / Internet Explorer	☐	☐	☐	☐
Other mathematics software	☐	☐	☐	☐

Which of the following are available at your school (check all that apply)	not at all	computer lab	my classroom
Excel	☐	☐	☐
FETCH (FTP)	☐	☐	☐
Geometer's Sketchpad	☐	☐	☐
Graphing Calculator 3.0/NuCalc	☐	☐	☐
Microsoft Word	☐	☐	☐
Netscape / Internet Explorer	☐	☐	☐

How have you used technology as a tool for teaching?
Discuss your interests in teaching geometry and measurement.
What concerns do you have about teaching geometry and measurement?
What are the biggest difficulties your students (are likely to) have in learning geometry and measurement?
How do you best learn mathematics?
Give an example of a time when you learned mathematics in your teaching practice.

APPENDIX C: POST-SURVEY

cptm

center for proficiency in teaching mathematics

2003 CPTM Institute
Geometry for Middle School Teachers
Institute Post-Survey (Teachers)

Name:	District/School:
Phone (for contact after summer):	E-mail (for contact after summer):

How comfortable are you in *working* with (check one in each row);

	not at all	not very	moderately	very
Excel	☐	☐	☐	☐
FETCH (FTP)	☐	☐	☐	☐
Geometer's Sketchpad	☐	☐	☐	☐
Graphing Calculator 3.0/NuCalc	☐	☐	☐	☐
Microsoft Word	☐	☐	☐	☐
Netscape / Internet Explorer	☐	☐	☐	☐
Other mathematics software:	☐	☐	☐	☐

How comfortable do you think you will be in *teaching mathematics* with (check one in each row);

	not at all	not very	moderately	very
Excel	☐	☐	☐	☐
FETCH (FTP)	☐	☐	☐	☐
Geometer's Sketchpad	☐	☐	☐	☐
Graphing Calculator 3.0/NuCalc	☐	☐	☐	☐
Microsoft Word	☐	☐	☐	☐
Netscape / Internet Explorer	☐	☐	☐	☐
Other mathematics software:	☐	☐	☐	☐

How do you expect to use technology differently next school year as a tool for teaching mathematics?

How will this Summer Institute experience affect other aspects of your teaching practice next school year?

How have your *interests* in teaching geometry and measurement changed?

How have your *concerns* about teaching geometry and measurement changed?

What were the biggest mathematical challenges you faced this week in learning geometry and measurement?

Describe a specific experience from the Summer Institute where you learned mathematics.

Why is this experience significant to you?

Describe an experience from the Summer Institute that you would share with a colleague. What about this experience stands out for you?
What did you learn about *mathematics* from attending the Summer Institute?
What did you learn about *learning mathematics* from attending the Summer Institute?
What did learn about *teaching mathematics* from attending the Summer Institute?
We will conduct Summer Institutes in the future. What would you keep the same about the mathematics course? What would you keep the same about other aspects of the Summer Institute? What would you change about the mathematics course? What would you change about other aspects of the Summer Institute?
How can we help you use the material from the Summer Institute in your teaching next year?