THE PROCESS OF TEACHER CHANGE: A LONGITUDINAL STUDY OF FOUR MIDDLE SCHOOL MATHEMATICS TEACHERS' EXPERIENCES DURING AND AFTER A TWO-YEAR PROFESSIONAL DEVELOPMENT PROGRAM.

Dissertation

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ABSTRACT

Helping teachers access new knowledge about how students learn and developing teachers with skills to continually access new knowledge must become goals for professional development. As we learn more about how people learn mathematics, teachers must be able to access and utilize that knowledge without having to undergo another season of reform. Thus, in keeping with reform themes, professional development opportunities should develop teachers who reflect on their practices, search out solutions to identified problems, and use multiple tools to assess the effectiveness of those solutions. Full understanding and implementation of the process will assist teachers in initiating changes on their own.

One goal of this study was to document changes that four middle school mathematics teachers made during and after a two-year reform-minded professional development program, and to understand the motivations behind those changes. A second goal was to understand how these professional development practices promote the practice of self-generative change. This goal was accomplished by comparing the teachers’ experiences to the proposed cycle of change, a model promoting the practice of self-generative change. The data included documents and videotapes collected during the professional development program, and observations of the teachers’ classrooms and interviews with the teachers two years after the program.

This study found that the reform-minded professional development practices utilized in the program did result in changes in all four teachers' teaching practices. All of the teachers made changes during the program that matched the goals of the professional development program, but one of the teachers made most of her changes two years after participating in the program. The generation of continuous change depended on the kinds of feedback the teachers used in the process of making change, and on the teachers' abilities to self-regulate their teaching. Self-generative change was also dependent upon the teachers' ability to accept responsibility for their successes and on the establishment of a method for determining goals. The beliefs and knowledge of the teachers impacted the amount and kinds of changes the teachers were able to make and their ability to continue the change process on their own.

Dedicated to:

My Husband
Thank you for putting your life on hold

and

My Family
With Love and appreciation for all your support and encouragement

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CHAPTER 1

INTRODUCTION

The reform efforts in mathematics education have taken many routes in their efforts to change mathematics teaching including new standards, new curriculum, and the incorporation of new knowledge about how students learn mathematics. These reform efforts have forced everyone involved in education to accept external standards (Beasley, 2000). Changing how teachers teach mathematics will allow for the greatest impact on student learning of mathematics (Weissglass, 1994). Clearly, this makes teachers the most important component in affecting change. Consequently, any successful reform effort will make use of knowledge about changes in teachers' beliefs and attitudes, changes in teachers' content knowledge, and changes in teachers' instructional practices (Borko & Mayfield, 1995; Borko & Putnam, 1995; Guskey, 1995). For teachers, the conflict between an emphasis on test scores, teaching for understanding, content knowledge issues, and being asked to use methods which they have never personally experienced as a student must be resolved. Beasley (2000) stresses that cultural change in the schools is needed before reform efforts aimed at professional development can have any serious impact. However, I would argue that professional development is the vehicle by which a change in school culture can be realized.

District officials often consider professional development to be a behaviorist issue, focusing on the transmission of knowledge from an expert to the novice (Spillane, 2002). District officials viewed teachers as externally motivated, versus being internally motivated to change, and cited resistance and inertia as the primary challenges for teacher change. In this belief system, teachers are seen as empty vessels into which new skills for teaching can be placed. Because of this belief, professional development opportunities take on an additive nature (Smith, 2001) where new skills are added to the skills teachers already have. However, these professional development programs are not designed to challenge the beliefs underlying old teaching practices. If these new skills are implemented at all, teachers often adapt the new practices to meet the old belief system (Franke, Fennema, & Carpenter, 1997). Thus, no great change occurs in how teaching happens. Consequently, no great change occurs in student learning. Without a break in the cycle of viewing professional development as additive, training for teachers still occurs in this traditional fashion. Teachers understand that the nature of the changes they are asked to make in the reform environment are vastly different from current culture they are experiencing. The conflict teachers perceive between what the current administration expects from them and the kinds of teaching promoted by the National Council of Teachers of Mathematics (NCTM) in the *Principles and Standards* (2000) may explain the resistance to change that administrators claim teachers exhibit. Teachers need to learn how to negotiate and affect the conflicting cultures to which they are held accountable. Traditional methods of professional development do not provide teachers with the tools to do this.

The professional development for mathematics teachers must be of a transformative nature instead of just an additive nature (Smith, 2001). Traditionally, consistent with behaviorist beliefs, teachers have experienced professional development sessions that "involve the addition of new skills to an existing repertoire" (Smith, 2001, p. 4). Many mathematics teachers have experienced mathematics "under a paradigm of instruction and learning in which memorization, repetition, speed, and correct answers were of paramount importance" (p. 3). Consequently, many of those teachers hold beliefs about the learning and teaching of mathematics that are in conflict with the beliefs of reform (Borko, Davinroy, Bliem, & Cumbo, 2000; Cooney & Shealy, 1997; Hawley & Valli, 1999; Thompson & Zeuli, 1999). To address this discrepancy, Smith calls for professional development opportunities that challenge teachers' beliefs about the teaching and learning of mathematics, increase teachers' knowledge about mathematics and the learning of mathematics, and provide teachers with models of reform practices. Essentially, the reform movement is calling for a change in the culture of school mathematics.

In an exploration of the National Staff Development Council's principles of professional development, Lewis (2002) describes these principles as addressing issues of form, duration, collective participation, content, active learning, and coherence for professional development programs. According to Lewis, professional development efforts that utilize teacher networks of longer duration, and that involve teachers in collaborative problem solving and the study of content have the greatest chance of impacting teaching practice. Additionally, teachers need to be actively engaged in observing each other and reviewing student work. Finally, teachers desire programs that are relevant to other activities in which they are involved. This translates into a need for professional development providers to create situations that are flexible in addressing the needs as perceived by teachers. Operating inside a vision of professional development that is aligned with teachers' concerns, we must address the fact that teaching is a complex task which occurs inside varying contexts. These contextual situations are very different for each teacher. Thus, the need exists for professional development opportunities that take into account the dynamic situations in which teachers work (Guskey, 1995).

Helping teachers access the knowledge currently available is one goal of reform efforts, but developing teachers with skills to continually access new knowledge must be an additional goal. As we learn more about how people learn mathematics, teachers must be able to access and utilize that knowledge, without having to undergo another season of reform. If teachers only learn about current knowledge, mathematics education will become stagnant again as soon as current knowledge is outdated. An additional element of cyclical, self-induced change must become one of the many skills teachers develop. Franke, Carpenter, Levi, and Fennema (2001) call this element "generative change." Generative change is seen as helping teachers become continuous learners, even when they are not participating in a professional development program. Teachers who create generative change are teachers who reflect on their practices, search out solutions to identified problems, and who use multiple tools to assess the effectiveness of those solutions.

Problem Statement

Many professional development providers have moved to models that are aligned with the National Staff Development Council's principles of professional development (Lewis 2002) and the recommendations for professional development of mathematics teachers made by NCTM (1991). The long-term effects of such programs are just now becoming available for study. The goals of these programs involve changing teaching practices in a manner consistent with mathematics reform ideas (Borko, et al., 2000; Franke, Fennema, & Carpenter, 1997; Jones, et al., 2000; Swafford, Jones, Thornton, Stump, & Miller,1999). While past efforts at professional development tended to be isolated, short-term experiences focusing on specific skills, current efforts are long-term and encourage teachers' examination of their beliefs about teaching and learning as they modify their practices. Although these programs have brought about many changes, the lasting impact of these programs is still in question. By lasting impact, I mean the ability of these programs to develop in the participating teachers an ethic of change; do these programs produce teachers who continue to change after the program ends, or do the teachers only make changes while they have access to the program's support structure?

Fullan (1993) supports the training of teachers in a process of continual inquiry, reflection, collaboration, and mastery of self-identified areas for change. Combining Fullan's change cycle with the process of self-reflection (Zimmerman, 2000), this study suggests a model of the cyclical process through which teachers necessarily progress as they self-initiate and enact change in their teaching practices. Beginning with a self-identified goal, the teacher selects an avenue for exploration. Once a goal of personal interest is selected, the teacher begins a process of inquiry which involves attempting the implementation of a new teaching technique or method, monitoring the implementation, and reflecting on the outcome. Through personal reflection and collaboration with others, the teacher makes modifications to the implementation and repeats the inquiry process. Once the teacher is satisfied with the implementation, the teacher transitions into the mastery phase of the change cycle. During this phase, the teacher takes time to recognize and acknowledge successful attempts at change, shares new knowledge with others, and begins the formulation of new goals. Once possible new goals are identified, the teacher begins to move through the cycle again.

This study seeks to understand how teachers progress through this change cycle. Specifically, this study will focus on how current professional development models encourage teachers to monitor their own change process. This study will involve the identification of changes made during and after the program, including any regression to pre- or early-program practices. Using observation and interviews with the teachers, their attempts at change will be examined through the lens of the proposed change cycle to increase our understanding of self-generative change in teachers trying to reform their teaching practices. As teachers learn to use feedback to inform their teaching, they become involved in a cycle of continuous change. Creating teachers who are agents of change (Fullan, 1993) must become the foremost goal of professional development, to prevent the constant need for reform movements. The No Child Left Behind Act (NCLB) of 2001 calls for teachers to pursue continuous improvement through advanced certification and credentialing after achievement of the highly qualified teacher status.

Unless teachers learn how to monitor their own change and to create change on their own, the nation will continue the pattern of intensive, expensive reform efforts. Empowering teachers to create and implement change can make resources available for other needs. This study will provide much needed information about how teachers can become the instigators and perpetuators of change.

Focus Questions

Specifically, this study will examine the following:

1. What specific changes did the teachers make in their practices during and since the two-year period encompassing the program and to what do the teachers attribute those changes?
2. Of those changes that were made during the program, which changes have been sustained or eliminated during the year following the end of the program and why?
3. Through what stages do teachers cycle during the change process?
4. What patterns appear in the teachers' dispositions toward reflective practice, continuous change, and in their thinking about and practice of teaching mathematics as they cycle through the change process?

Theoretical Framework

The underlying framework for any study aimed at changing teachers' practices must be understood to be Critical Theory (Lincoln and Guba, 2000). The very nature of professional development is to move teaching toward a desired goal. In designing professional development, the first step must be an examination of current practices. At some point, a difference between current practice and desired practice is perceived to exist. Thus, professional development is implemented with the goal to moving current practice towards desired practice. Glesne (1999) labels this as critical ethnography which is grounded in Critical Theory. The fact that some action is taken to change teachers' practices is the important component in this identification. I must acknowledge that I desire to see teaching practices moving towards the reform-like end of the spectrum, as envisioned in the *Principles and Standards* (NCTM, 2000) and supported by constructivist, social constructivist, and social cognitive theories of learning. While this research project attempts to examine what teachers are doing, and not to move teachers from what they are doing, the Critical Theory perspective does bring to light the fact that some practices were more valued than others during the program and by the researcher. Judgments about whether teachers have advanced or regressed in their practices will be based on this value system.

Current reform efforts are impacting everything from the textbooks teachers use to the laws governing how schools operate, and these efforts can often seem to be in opposition to each other. On an individual level, many teachers enter the profession with a passion for making a difference in students' lives. At least early in their careers, many teachers have a desire to create change. Therefore, teachers often experience internal and external pressure to change. Simultaneously, the structure of schools creates a hierarchical system, which is inherently resistant to change. The factory-model that Lewis (2002) mentioned does not provide teachers with useful skills when confronted by these opposing demands. Consequently, teachers start placing the blame for any lack of change on the external factors over which the teachers have no control.

Fullan (1993) would argue that teachers are not being irresponsible or reticent about change, nor do they lack motivation. Through his examination of the paradoxical world in which teachers live, we are made aware that teachers do not have the proper tools in hand to alter their practices inside this conflicting environment. Cochran-Smith (1991) argues that in preservice education, teachers “are not deliberately socialized into assuming responsibility for school reform and renewal” (p. 285). Once they leave their preservice experiences, teachers encounter a hierarchical structure that clearly does not socialize nor encourage teachers in habits of change. In the next sections, two different sets of skills will be examined for their importance in teacher change. These two sets of skills will be combined together in a proposed model for the cycle through which teachers go as they implement change in their teaching practices.

Fullan’s Change Capacities

Teachers often enter the profession because they want to make a difference (Fullan, 1993). As Fullan explains, teachers’ desires to make a difference for their students requires teachers to be in tune with the needs of their students and be prepared to respond to those needs. Identifying needs and having the skills and necessary preparation to respond to identified needs is what permits teachers to generate changes on their own, without outside mandates. Thus, Fullan’s four core capacities for building change become important skills for teachers. These four capacities are: personal-vision building, inquiry, mastery, and collaboration. Offering teachers these skills of change should become a goal of reform-minded professional development programs that seek to prepare teachers to continually generate change. The following sections explain Fullan's four capacities.

Teachers need to examine the reasons they entered teaching and the goals they hope to accomplish with their lives, rather than spending time wondering how they are going to implement desired or mandated reforms (Fullan, 1993). Teachers trying to implement change should not start by trying to understand how they will implement change. Instead, teachers should approach change by first developing an understanding of their personal desires and motivations (Block, 2002). From this understanding of themselves, teachers then generate a personal-vision that incorporates their desires. Building this personal vision means "examining and re-examining why we came into teaching" (Fullan, 1993, p. 2). Once a teacher has a clear personal vision, desired changes in teaching practices should then be measured against this personal vision. By matching their goals with their personal vision, teachers are more likely to stay committed to a goal, better targeting their efforts and time.

The next skill in Fullan's (1993) model is inquiry. By inquiry, Fullan means persistent questioning, "internalizing norms, habits, and techniques for continuous learning" (p. 2). Because information is increasing at astronomical rates, the knowledge that teachers possess when they leave their teacher education program will become obsolete fairly quickly. Therefore, we can no longer operate teacher education or professional development programs under our former practices of knowledge transmission. In these traditional practices, the expert attempted to convey a cache of information to the newly inducted novice. The novice was seen as an empty receptacle for the information. Instead of reinforcing those practices, professional development programs should encourage teachers in practices of inquiry. In these practices, after identifying areas in which they need or want more information, teachers proceed to research those topics using multiple methods. By learning how to identify and investigate an area of interest, teachers learn to create new knowledge for themselves. Instead of approaching teaching as a set of skills and concepts to memorize and master, teachers should be encouraged to view the process as a constant cycle of inquiry, questioning, analysis, and evaluation.

The third skill is one that is often neglected in traditional inservice structures: mastery. Mastery includes developing a complete understanding of the topic which the teacher has inquired and acknowledging that complete understanding. As Fullan (1993) states, “people behave their way into new visions and ideas, not just think their way into them” (p. 3). Clearly, one of the skills teachers should possess is the skill of identifying their own successes. Part of developing this skill requires opportunities to practice new concepts and ideas. By practicing the behavior, teachers gain a deeper understanding of all the complexity of the concept. Traditional professional development programs often give teachers a brief look at a topic and allow no time for practice of the skill in a supportive environment. Teachers are sent back to the classroom after only knowing the concept as an idea, and are then supposed to implement the new method effectively. Fullan encourages us to look at mastery as a process and not as an end result. Teachers need sufficient time and outlets for practicing new skills and ideas, with their classrooms being only one of the places where practice occurs. However, instant mastery should not be the implication. A process of trying, modifying, and trying again should be the way to mastery.

The final essential skill is collaboration. Teachers must learn to work with others: other teachers on staff, teachers in other buildings, administrators, parents, and community members. “The ability to collaborate on both a small- and large-scale is becoming one of the core requisites of postmodern society” (Fullan, 1993, p.3). Cochran-Smith (1991) discusses the idea of collaborative resonance wherein teachers work with other teachers in a community of co-learners. Frykholm (1998) discusses a community of learners which includes inservice and preservice teachers along with higher education faculty. These examples of collaboration encourage teachers to share ideas, decreasing the isolation of teachers. The structure of the school day often makes collaboration of teachers difficult. However, inside the context of a professional development program, the group may be able to make modifications or arrangements that allow for teacher collaboration. The power of several as compared to the power of the individual can be a driving agent of change.

Although Fullan (1993) does not present these four skills as a cycle, one can begin to see a pattern through which teachers using these four skills would cycle in their professional growth. At the start, a teacher begins by defining a personal vision based on what the teacher thinks is important. With this vision in mind, the teacher sets in motion a process of inquiry about personal teaching practices. A constant questioning of practices reveals where the teacher is consistent or inconsistent with the personal vision. Upon discovery of inconsistencies, the teacher either has to reevaluate the personal vision, or seek out ideas or practices that would help achieve the goal.

At this point, collaboration and mastery come into play. In wanting to achieve the personal vision, a teacher would begin to progress towards mastery of the skills or concepts that the teacher has deemed necessary. Collaboration is the how and where of mastery. How the teacher finds these new ideas or concepts is by collaboration with others. Mastery is accomplished through continued practice, but the collaboration provides support for this practice. Once mastery is obtained, the teacher reevaluates the personal vision. If the vision has been achieved, then a new personal vision is established. If the vision has not been accomplished, further efforts are made through inquiry into new ways of addressing the vision. The process of mastering those new skills or concepts begins. From the inquiry process onward, the teacher gains support and empowerment through collaboration.

Although teachers set their goals based on their personal vision, Fullan does not suggest how teachers should deal with a change in personal vision if the shift in personal vision happens while a teacher is in the midst of pursuing a particular goal. For example, Ferrini-Mundy (1997) observed that the interests of a group of elementary teachers studying the *Principles and Standards* (NCTM, 2000) became more aligned with the vision in that document as the year progressed. As the teachers learned more about the *Principles and Standards*, more of them became interested in joining a school reform effort. The process of learning about and implementing the *Standards* was "evolutionary and open ended." From her description, the teachers in the study appeared to have been flexible in their thinking and not rigid in their plans.

The example that Ferrini-Mundy (1997) offers is not in disagreement with Fullan so much as pointing to a weakness in Fullan's model. Constant monitoring of one's progress and willingness to change course allowed the teachers in Ferrini-Mundy's study to make adjustments in their goals as their personal vision changed. To address this need for flexibility and as a way to continually monitor one's personal vision and adherence to that vision, I propose the use of self-regulation (Zimmerman, 2000). I will discuss the incorporation of self-regulation later in this chapter.

Several other models of teacher change exist (Swafford, et al., 1999; Steffe, Thompson, & von Glasersfeld, 2000). These models or methods aimed at teacher change focus on moving teachers from one place to another. For example, a goal might be to move teachers from using only individual student work to using cooperative learning experiences. These models are important and incorporate many of Fullan's (1993) four components, but with a slightly different emphasis on the person. Fullan suggests continuous self-evaluation and self-monitoring in the inquiry phase, but does not provide a mechanism by which these would occur.

The difference in emphasis lies in the reflective components of those programs. While professional development programs generally encourage reflection, it is often accomplished as interaction between the teacher and another person, via a journal or class discussions. Fullan also utilizes this kind of reflection in his collaboration skill, but suggests an additional aspect of reflection: internally generated and evaluated reflection.

Perhaps it is easier to think of Fullan's reflection as an interaction between the teacher and the teacher's self, or self-regulation. Instead of relying solely on feedback from others, the teacher develops skills of self-assessment and learns to take action based on that self-evaluation. However, Fullan does not offer a mechanism for this self-reflection. Thus, I introduce Zimmerman's (2000) model of self-regulation.

Self-Regulation

Self-regulation is "self-generated thoughts, feeling, and actions that are planned and cyclically adapted to the attainment of personal goals" (Zimmerman, 2000, p. 14). This is the internal dialog Fullan (1993) encourages. Important to the definition of self-regulation is the interrelatedness of the person, behaviors, and the environment. According to social cognitive theory, internal personal factors, behavior, and environmental events interact with each other in what Bandura (1997) calls triadic reciprocity. These three factors will have varying strengths of influence in different situations, but all three serve to influence human agency (Bandura, 1997). Because behavior, environment, and personal factors vary in the strength of their influence in different situations (Bandura, 1997), a person's ability to self-regulate is context related, and dependent on a cyclical feedback loop (Zimmerman, 2000).

The Cycle of Self-Regulation

Zimmerman (1997) presents three phases through which the cycle of self-regulation occurs: forethought, performance control, and self-reflection. Self-regulation begins with forethought, the "influential processes that precede efforts to act and set the stage for [action]" (p. 16). Analysis of the task at hand is the job of forethought, and includes goal setting and strategic planning for accomplishing determined goals. However, the personal, behavioral, and environmental factors are at work impacting the person's sense of efficacy, motivation, and value for the task. These impact the person's goal orientation. Therefore, as one proceeds with the task with the established goals, things can happen that may require a return to the forethought phase. Success or failures with established goals and strategies and changes in environment are just some of the examples of situations that cause changes in a person's sense of efficacy or motivation. Therefore, the forethought phase reflects the changing and reciprocal relationship between the person, the environment, and behaviors.

The next phase of self-regulation is called performance control (Schunk, 2001). Performance control involves the processes that occur as a person is trying to implement the actions determined as necessary in the forethought phase (Zimmerman, 2000). During performance control, a person is involved in self-observation, self-judgment, and self-reaction. These three subprocesses serve as a means for managing personal actions, which includes metacognitive activities, and to provide instruction for accomplishing predetermined tasks. These same subprocesses are at work during the self-reflection phase, the third phase of self-regulation. During this phase, judgments are made about task completion by comparing personal performance to some standard (Zimmerman, 2000). The standards of performance include externally established mastery criteria, such as criterion referenced tests, personal past experience, normative measures, such as comparing oneself to a role-model, and collaborative measures, as in fulfilling a certain role in a group (Zimmerman, 2000).

The Subprocesses of Self-Observation, Self-Judgment, and Self-Reaction

While managing progress during the performance control phase and assessing progress during the self-reflection phase, the individual needs some tools. The subprocesses are these tools. The first subprocess, self-observation, involves the individual being cognizant of personal actions (Zimmerman, 2000) and noting how specific conditions affect personal progress (Schunk, 2001). Self-observation is similar to watching a videotape of yourself, but in real-time. During self-observation, the individual is observing and recording actions and results, but is not making any judgments about those things. The second subprocess, self-judgment, “refers to comparing present performance with one’s goals” (Schunk, 2001). Self-judgment may take on different forms, depending on the phase of the self-regulation process in which self-judgment occurs. During the performance control phase, the subprocess of self-judgment usually takes the form of receiving attributional (ability) feedback from self or others. Examples of attributional feedback would be telling a teacher she is good at managing cooperative groups, or when a teacher feels that a lesson went well. Sometimes this feedback involves effort feedback, which involves affirming the effort of a teacher without commenting on the ability. For example, a professional development provider might comment on how hard a teacher is trying to incorporate discussions in the classroom. Interestingly, Schunk (2001) states that the form of feedback is not as important as the credibility of the feedback. In the self-reflection phase, self-judgment is likely to be accomplished by comparing one’s actions to some standard. The third subprocess, self-reaction, accounts for the ways an individual can react to progress in goals. Self-reactions can be categorized as self-satisfaction and adaptive inferences (Zimmerman, 2000). Self-satisfaction addresses the degree to which the individual is satisfied with performance of a task or accomplishment of the goal. Adaptive inferences “are conclusions about how one needs to alter his or her self-regulatory approach” (Zimmerman, 2000, p. 23). A person may respond in ways that serve to protect their self-efficacy for a task by assigning blame for lack of success in different ways. A person may also look for new strategies or make modifications to old strategies. Again, self-reaction can occur during the performance control and self-reflection phases. During performance control, the reaction may be more directed toward tasks, while the self-reflection phase may result in reactions surrounding accomplishment of goals. It is worth noting that in Zimmerman (2000), these subprocesses are not shared by the performance control and self-reflection phase, but rather are delegated to one phase or the other. However, a reading of Schunk (2001) and discussion with colleagues during a course has led me to the conclusion that effective self-regulation requires that these subprocesses take place during both performance control and self-reflection. Not only do teachers have to observe, judge, and decide how to react while they are in the midst of a lesson, but they have to perform those same tasks after a lesson to be truly reflective. Conversely, teachers who only examine their teaching after a lesson miss the information that could have been gathered by observing, judging, and reacting during the lesson. Therefore, I have chosen to modify Zimmerman’s original model to include the subprocesses in the performance control and in self-reflection phases.

The Teacher Change Cycle

In this section, I will explain how I have combined Fullan's (1993) four capacities for change with Zimmerman's (2000) cycle of self-regulated learning to create a teacher change cycle. A diagram of the proposed model can be found in Appendix A. This model consists of a cycle of three stages: vision/forethought, inquiry, and mastery. The first stage, vision/forethought, is a combination of Fullan's (1993) vision building skill and Zimmerman's (2000) forethought phase. The second stage, inquiry, uses Fullan's inquiry skill with Zimmerman's self-regulation phases embedded within the inquiry phase, giving the inquiry stage it's own interior cycle. Fullan's inquiry skill is a persistent questioning and evaluation of one's teaching practices. Zimmerman's self-regulation process offers a structured method for this inquiry. The third stage of my proposed Change Cycle is the mastery stage. As Fullan uses mastery, it is the process of becoming comfortable with a new teaching idea. In the proposed model, Fullan's process of becoming comfortable with an idea is part of the inquiry stage, and the mastery stage begins when a teacher reaches that comfort level. The mastery stage in the proposed model involves the teacher affirming her achievements with the new idea.

As I have conceptualized the process, the Change Cycle begins in the vision/forethought stage. In this stage, the teacher examines possible goals and avenues of exploration. Consideration of the teacher's personal goals and motivations influences the teacher's task analysis, and decisions are made regarding a plan of action. The teacher establishes goals and proceeds onto the next stage, inquiry. Although I am aware that actions sometimes precede goals, this change model is designed to represent deliberate efforts at changing one's teaching practices, rather than accidental changes.

During the inquiry stage, the teacher researches areas of interest or attempts tasks that were identified during the vision stage. Inquiry involves testing a hypothesis, reevaluating the hypothesis, and testing the modified hypothesis. The inquiry stage cycles through three steps: enact, performance control, and self-reflection. Enact is the first step of inquiry as defined here. During the vision/forethought stage, a teacher establishes a goal and develops ideas about how to proceed with the goal. The enact step is the teacher's attempt at implementing the plan established during the goal setting phase. During the enact step, the teacher employs Zimmerman's self-regulation phase of performance control. During performance control, the teacher is observing and noting how the attempt is progressing, and making judgments about the success of the attempt.

Once the teacher has tried out the new idea or method in the enact step, and has simultaneously engaged in performance control, the teacher then engages in Zimmerman's self-reflection phase. During the self-reflection phase, the teacher reflects the attempt made during enactment and begins to examine the observations made during the performance control, making decisions about how the effort attempted should be modified. The teacher then repeats the cycle of enact, performance control, and self-reflection. Throughout the inquiry stage, others contribute to the efforts of the individual. Others might include colleagues, students, administrators, university personnel, professional development providers, and any other people that provide the teacher with some form of feedback. Collaboration with others is an important form of feedback and is included in the self-judgment and self-reaction pieces of both performance control and self-reflection.

At some point during the self-reflection step, the teacher will determine that the goal or task has been accomplished. The teacher will find a comfort level with the change, feeling that energy could be diverted to other changes. Acknowledgment of moving into the mastery phase may take the form of the teacher offering advice to other teachers in the building, or may go as far as the teacher presenting at a professional conference. The mastery stage is included to encourage teachers to take the time to recognize their numerous successes. Fullan (1993) uses the mastery phase of his cycle as a time of practice. Although I agree that practice is necessary in achieving mastery, I have placed the practice necessary to achieve mastery inside the inquiry stage. The mastery phase in the teacher change cycle presented here occurs after a skill or goal is mastered. During the mastery stage, teachers can collaborate with others to share the knowledge they have gained. Following mastery, the teacher returns to the vision/forethought stage and the cycle continues.

The reader should be aware that the impact of beliefs about mathematics, beliefs about teaching, self-efficacy, and knowledge influence each stage and step of the model. In the model, this influence has been represented by gray shading. Social cognitive theory, on which Zimmerman's self-regulation theory is based, acknowledges the importance of these factors in influencing the individual. As will be thoroughly discussed in the literature review, these factors also play important roles in the professional development of teachers. Teachers' beliefs, especially about mathematics and teaching, and the knowledge a teacher possesses, including content knowledge, influence the goals a teacher selects, the models a teacher uses for comparison, and the very nature of the teacher's self-reflection. Self-efficacy also impacts the goals a teacher selects. Teachers are more likely to select tasks for which they feel efficacious (Bandura, 1997). Therefore, the influence of these items should be seen as permeating the entire process.

Consistency With Theories of Learning

Teachers work in complex environments and any consideration of professional development that does not take into account the context in which a teacher is working would be incomplete and careless (Fullan, 1993; Martin, 1993). A distinction should be made between thinking of instruction "as what teachers do," and what instruction really is: "interactions involving teachers, students, and content" (Cohen & Ball, 2001, p. 75). Instruction happens in an environment that is filled with context. According to Martin, if one views the learning of new teaching strategies as learning new forms of communication, then the teacher is involved in a dynamic process that requires negotiating meaning between the teacher and students, and between the teacher and other professionals. From a Vygotskian perspective, we understand that knowledge is socially constructed, which appears to be a very appropriate way of thinking about teacher development. Thinking about teachers involved in traditional professional development, several situations occur. First, the teachers enter the setting with different knowledge. Therefore, while interacting with the new idea being presented, the teachers are going to construct different understandings of that new concept. As teachers carry this new idea back to their classrooms, they begin interacting with very different groups of students.

Remembering that the context in which the teacher practices affects the teacher's knowledge development, leaving the teacher isolated in the classroom to work towards mastery of the idea would likely result in vastly different results for each teacher. Given this construction of practice, it becomes understandable how the implementation of reforms goes awry. Teachers often have different opinions about the success of such methods, and these opinions may be the result of teachers being isolated from each other. This makes clear that the social contextualization and the individual construction of teachers' learning must be accounted for in any professional development attempt.

In addition to the already discussed aspect of learning being conducted in a social context, Rainer (2001) enumerates principles established by Lambert that characterize social and psychological perspectives of constructivist learning theory which are relevant in schools. The list includes mention of reflection being necessary to knowledge construction, and learners playing a critical role in assessing their own learning. Clearly, these two ideas are interrelated. For teachers engaged in professional development, understanding their own development is a direct result of reflecting on their teaching, or what Fullan (1993) would call practicing the skill of inquiry. Working with other teachers can provide additional information to help a teacher reflect. This collaboration also creates a context in which the community of professionals creates a shared understanding of the topic of study.

Dealing with Teachers' Beliefs

Compounding the complexity of teacher development, we must remain aware that teachers bring with them beliefs about teaching, learning, mathematics, and the world.

Many teachers hold beliefs which are incompatible with current reform efforts (Senger, 1998). At the same time, teachers moderate their learning through their beliefs: the same beliefs that may be the target of the learning (Borko & Mayfield, 1995). As if things were not already complicated enough, not only are beliefs difficult to observe, the teachers are not always cognizant of the beliefs they hold (Senger, 1998). However, when working with teachers for an extended period of time, opportunities arise that enable beliefs to become more apparent.

Reflection can serve as a tool to help make beliefs more explicit. Artzt and Armour-Thomas (2002) used reflection as the main means of helping preservice teachers question their beliefs. Through reflective journaling and structured lesson observations, the preservice teachers examined situations that challenged their beliefs about learning and teaching. While some may argue the ethics of troubling another person's beliefs, a teacher who is unaware of their existing beliefs has no chance of supporting those beliefs. A teacher can only defend their actions if they truly understand the underlying beliefs. The reflective cycle and collaborative process of establishing a personal vision, inquiry about personal practice, and collaborative efforts will place teachers in a position where their beliefs may become more apparent. Only then will teachers be able to assess whether their personal beliefs are aligned with reform standards. Recognition of a misalignment between personal beliefs and those beliefs surrounding reform measures may be a first step in the teacher change process.

CHAPTER 2

REVIEW OF LITERATURE

Reform Mathematics

In 1989, the National Council of Teachers of Mathematics (NCTM) released a landmark document entitled *Curriculum and Evaluation Standards for School Mathematics.* Along with two other documents, *Professional Standards for Teaching Mathematics* (NCTM, 1991) and *Assessment Standards for School Mathematics* (NCTM, 1995), these three documents "represented a historically important first attempt by a professional organization to develop and articulate explicit and extensive goals for teachers and policymakers" (NCTM, 2000, p. ix). With these three documents, the school mathematics community embarked upon a grand effort that is still having an impact 14 years later. The introduction of the 1989 document marks the beginning of the reform movement in school mathematics. In 2000, NCTM released *Principles and Standards for School Mathematics* (*Principles and Standards),* a revised and updated version of the *Curriculum and Evaluation Standards for School Mathematics*. This new document sustained the scrutiny of classroom teachers and mathematicians, as well as others outside the mathematics community as part of its development. The *Principles and Standards* represents a view of teaching mathematics that is based on the most current knowledge of how students learn mathematics and reflects ideas about how teachers can best facilitate all students in their learning of mathematics. This view includes the belief that all students should be empowered to do mathematics, that students construct their own meaning, that mathematics should be taught as a dynamic collection instead of isolated facts, and that each students' knowledge is created through personal experience and assimilation (NCTM, 1991). When discussing reform in mathematics education, most authors refer to a movement that is grounded in the guidelines of the NCTM document. Along with being grounded in the guidelines of the *Principles and Standards*, efforts that qualify as reform also share the common framework of being grounded in current theories of learning. These efforts generally adopt some form of constructivism and include aspects of social influence from social cognitive or social constructivist views of learning (e.g., Borko, Davinroy, Bliem, & Cumbo, 2000; Franke, Fennema, & Carpenter, 1997). Consequently, to understand the reform movement, one must first understand the *Principles and Standards* and current theories of learning.

Within the *Principles and Standards* document, recognition is given to the impossibility of unanimous agreement within the teaching and mathematics communities on all ideas about how school mathematics should be taught and what should be included. Acknowledging this fact, the document serves as "a guide for focused, sustained efforts to improve students' school mathematics education" (NCTM, 2000, p. 6). Because the *Principles and Standards* represent a vision about school mathematics, the specifics of a curriculum are left to the discretion of the local school district (NCTM, 2000). This lack of specificity leaves teachers in the position of needing to meld together the vision of school mathematics represented in the *Principles and Standards*, the view of school mathematics supported by the teacher's local school district, the vision of school mathematics represented in the selected curriculum materials, and the teacher's personal view of mathematics teaching**.** As the students enter the classroom, the teacher then also must contend with the students vision of what mathematics is and should be. Clearly, bringing together these different ideas about what should take place in the mathematics classroom is complicated. Any piece of this negotiation process would be worthy of study, but I am particularly interested in how teachers negotiate the triad of the vision presented in the *Principles and Standards*, personal beliefs, and the context of the local curriculum. Therefore, I will restrict this discussion to aspects connected to the teacher and will not be exploring the added dimension that students bring to the picture when their personal beliefs and views are added to the mix. However, because of the nature of teaching, completely removing students from the discussion is impossible, but I will discuss only the salient facets of student involvement.

Understanding what the *Principles and Standards* say to teachers and the implications it holds for teachers is the logical place to start. However, Ball (1996) warns that "there exists no single 'it' to which the reforms aim, no specific set of steps that teachers must enact" (p. 504). Readers of the *Principles and Standards* must understand then the document is not a prescription for daily activity in every mathematics class at every grade level. This document seeks only to create the vision of how mathematics teaching can be better, but does not presume to have the single solution to how this vision can be enacted.

The tone of the current era of mathematics education is one of accountability. Based on the mandates laid forth in the NCLB Act of 2001, many aspects of mathematics education are on the way to being “standardized” so these aspects can be measured in a quantitative way. Although each state is still permitted to determine its own mathematical curriculum, each state is now required to create such a curriculum. State tests are then administered to test students on this standardized mathematics curriculum. This form of standardization tends to focus on content and topics students should know and be able to do. However, because these tests are given to large populations, the tests are generally standardized themselves. These reforms do not generally address the ways teachers are teaching the content. Thus, the issue of having standards in mathematics is very different from that of standardizing mathematics. The framework for this study was concerned with creating standards for mathematics, such as the *Principles and Standards* (NCTM, 2000) which encompass the content as well as the methods of delivery.

So if the *Principles and Standards* does not tell us what should be done on a daily basis, what does it tell us? It paints for us a picture of how students learn and how teachers facilitate that learning. Although an explicit statement connected to a particular learning theory is never made in the *Principles and Standards*, the picture of students collaborating to construct personal knowledge of mathematics strongly suggests some cognitive, social cognitive, social constructivist, and constructivist leanings. Based on this idea of how students learn, the role of the teacher becomes evident. Some specific guidance is given to teachers about their roles, but these guidelines are still fairly general.

In order to adequately function in these roles, teachers must possess some particular kinds of knowledge. This knowledge is not necessarily enumerated in the document, but several ideas such as strong content knowledge and knowledge of mathematics as a living discipline become necessary in light of the roles of the teacher as facilitator of learning.

In the following section, I will explore the explicit and implicit statements within the *Principles and Standards* (NCTM, 2000) that develop the picture of student learning in a reform classroom. These ideas will then be framed within the current theories of student learning. My goal in this discussion is not to explain each learning theory represented in the *Principles and Standards*. Rather, my intent is to make explicit the learning theories advocated within the Standards, and thereby, the reform movement. Using this view of student learning, I will explore the implications regarding the kinds of knowledge teachers need in order to create this rich learning environment. Following this discussion, I will explore how teachers learn and develop that knowledge.

What Reform Says About Student Learning

To understand what the reform movement has to say about student learning, the discussion must first observe what the *Principles and Standards* imply about student learning. Within the document itself, no single learning theory is posited as the preferred position. However, when reading the document, evidence appears that could direct one toward a particular end of the spectrum of learning theories. Beginning with the Equity Principle, the document supports a belief that all students can and should have access to "a coherent, challenging mathematics curriculum taught by competent and well-supported mathematics teachers" (NCTM, 2000, p. 12). This statement reflects a distinct shift from a commonly held belief that only some students should be doing mathematics, based on ability, likely future choices, or past experiences. This belief shifts the focus from thinking that some people have natural mathematical ability to a belief that all people need to develop their mathematical ability. Some students may be more interested in mathematics and should be supported in their interest, but all students should obtain mathematical literacy.

Along with the shift in who should be doing mathematics, the *Principles and Standards* provide a description of the learning process. To accomplish the vision of the *Principles and Standards*, students should achieve an “alliance of factual knowledge, procedural proficiency, and conceptual understanding” (p. 20). These components are necessary “in the knowledge and activity of persons who are proficient [in mathematics]” (p. 20).

In the current reform climate, students should be learning for understanding. By this, I mean that students should possess mathematical proficiency in the five strands suggested by the National Research Council (NRC) (2001). These five strands are: conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. Having conceptual understanding of the mathematics one knows, means understanding the underlying foundations of mathematical ideas and understanding the relationships between ideas. Procedural fluency allows students to do mathematical processes, such as adding fractions or completing the square, accurately and efficiently. Procedural fluency also involves knowing when a procedure should be applied, such as knowing when to multiply together the numerators or denominators of fractions and knowing when to cross multiply. Strategic competency is the ability to reason through a mathematical problem, having available an arsenal of problem solving techniques. Adaptive reasoning, on the other hand, involves the ability to explain and justify the actions taken to solve a problem. Students should be able not only to solve a problem, but to explain how they thought about the problem, why they used the selected methods, and how the results make sense. Finally, students must have a productive disposition toward mathematics that allows students to see mathematics as valuable and useful, and to see themselves as being able to do mathematics.

Differences between experts and novices in physics, computer programming, and medicine appear in part because experts have more factual knowledge about the field. Experts store their knowledge in larger units than do novices, novices build naïve representations of problems from focusing on unimportant aspects of problems, experts have greater knowledge of schemas for problem types in the field, and experts have more strategies for approaching those problems (Mayer, 1992). Each of these differences could be classified as the result of lacking one or more of the five strands of mathematical knowledge. In order for students to move from being novices to experts of mathematics, they must be given sufficient experience with and exposure to mathematics that moves beyond procedural knowledge and allows for problem solving. But exposure alone is insufficient. Students must be given opportunities to function within and make choices about relevant problems, helping them develop strategic competence. This suggests a situative position on learning, in which knowing mathematics involves the relationship between the individual and the mathematical community, including the books, tools, and artifacts of mathematicians. In other words, one learns mathematics by being engaged in tasks that use the tools, symbols, and language of mathematicians. Students should be involved in authentic tasks that encourage mathematical thinking. In this way, students will make the move from novice to expert, by being placed in situations where factual knowledge, procedural proficiency, and conceptual understanding are all required and practiced.

Teacher Knowledge Necessary in a Reform Climate

An examination of the *Professional Standards for Teaching Mathematics* (*Professional Standards)* (NCTM, 1991) reveals some information about the kinds of knowledge required of mathematics teachers in the reform era. The *Professional Standards* categorizes the necessary knowledge base for teachers into the following categories: (a) knowledge of good mathematics teaching, (b) knowledge of content and of school mathematics, (c) understanding of how students learn, (d) knowledge of general and content specific pedagogy, and (e) knowledge of the self as teacher. What follows is an examination of how these categories of knowledge align with the knowledge base proposed by others. In addition to these five categories, I will propose an additional category of knowledge, practical knowledge. Although NCTM positions practical knowledge within each of its stated categories, I will argue that practical knowledge is important enough to warrant a separate category.

Knowledge of Good Mathematics Teaching

The first category of knowledge is somewhat different from the others in that it is more purely about experiences rather than knowledge construction, although the two are intimately related. According to NCTM (1991), teachers should have authentic experiences of learning mathematics in settings that model good teaching. In this study, those good teaching practices are those that reflect the vision of the *Principles and Standards for School Mathematics* (NCTM, 2000). Through the mathematics classes in which teachers participate as students, and in their preservice and inservice training, teachers develop their "ideas about what it means to teach mathematics, beliefs about successful and unsuccessful classroom practices, and strategies and techniques for teaching particular topics" (NCTM, 1991, p. 127). These prior experiences serve as powerful influence on teachers' practices.

Unfortunately, these prior experiences tend to be the antithesis of the *Principles and Standards* vision. Many inservice and preservice teachers understand mathematics as consisting of factual knowledge, skills, and algorithms. These teachers have very little conceptual understanding and lack connections between specific pieces of mathematical knowledge. This way of understanding mathematics develops because of the emphasis and kinds of teaching methods the teachers experienced as students. Asking these teachers to create a reform classroom where mathematics is dynamic, conceptual, and collaborative may be so far beyond the teachers' personal experiences as to be virtually impossible. If, however, these teachers are provided with opportunities to experience engaging mathematical activities that incorporate problem solving and conceptual understanding, their knowledge of mathematics and of what mathematics is can change.

Until teachers have had some personal experience with learning mathematics in constructivist ways, the reform classroom will remain but a dream. Therefore, teacher education and professional development experiences must provide teachers the kinds of learning opportunities that the teachers are expected to provide their students. This does not mean that teachers should practice the material in lessons they will teach. Instead, teachers should be involved in problem solving experiences designed to increase content knowledge and make connections between mathematical topics. Teachers should be afforded a safe environment in which they can take risks in their thinking. Until teachers know another way to teach, they will continue to recreate their own past experiences for students.

Knowledge of Content and School Mathematics

The second category of knowledge established by NCTM (1991) is content knowledge. Teachers need to know the mathematics they teach in a flexible, conceptual way (Borko & Putnam, 1996; NRC, 2001). As was discussed earlier regarding students' knowledge of mathematics, teachers should have the complete understanding represented by the five strands:conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. Teachers should understand the concepts as well as the facts and procedures involved in the mathematics they teach. They must also be able to think about mathematical situations and reason through problems in different ways, because students may approach problems differently. Teachers need adaptive reasoning to explain mathematics to students and to conduct mathematical discussions. Having a productive disposition toward mathematics influences the importance a teacher places on mathematics and contributes to the tone of the mathematics classroom. Not only must teachers have a complete understanding of the mathematics they teach, but they must also understand the mathematics their students will see in the future (Borko & Putnam, 1996).

Thompson, Phillipp, Thompson, and Boyd (1994) consider mathematical content knowledge as being computational, calculational, or conceptual. A computational perspective approaches mathematics as a set of procedures done out of context. Teachers with this kind of understanding of mathematics may have strong procedural fluency, but lack conceptual understanding (NRC, 2001). A calculational viewpoint focuses on the application of procedures aimed at obtaining correct answers. In this viewpoint, teachers have strong procedural fluency, conceptual understanding, and strategic competence. These students, however, lack adaptive reasoning skills that would allow them to explain, justify, and argue through problems. In a conceptual orientation, mathematics is viewed as interrelated ideas and a way of thinking. These teachers understand mathematics in a complete way, utilizing knowledge based on all five strands. The main problem with the calculational view is that the focus is only on procedures and not on understanding where the procedures fit into the whole picture. While a conceptual view is where reform efforts ideally place teachers, this perspective is difficult to achieve. Many preservice and inservice teachers do not have conceptual understanding of the content they teach (Ball, 1996).

In the literature on expert-novice understanding of content, not only is the kind of content knowledge important, but so is the organization of that knowledge. Mayer (1992) discusses the differences between experts and novices in chess, physics, computer programming, and medicine. From this research, experts have knowledge that is stored in large pieces; knowledge that allows for easy discrimination between salient features in problems, and connected information that allows for access of alternative strategies. If teachers have generally experienced mathematics in a computational way (Thompson, Phillipp, Thompson, & Boyd, 1994), their knowledge is not likely to be connected, discriminating, or full of alternative strategies. Thus, preservice and inservice teachers must be provided with experiences that will help transform their knowledge of mathematics from a disconnected set of facts to a well-connected web of concepts.

The greatest part of teachers' content knowledge is developed in the mathematics classes that teachers take prior to earning their teaching degree. This includes the elementary, middle, and high school classes along with any required college courses. In their review of research about how degrees and coursework of teachers affect student learning, Wayne and Youngs (2003) found that mathematics students who had teachers with masters or bachelors degrees in mathematics showed higher increases in standardized test scores than students with teachers who had non-mathematics degrees of equal rank. From these studies, we can conclude that the teachers' knowledge of how to do mathematics, which comes from the mathematics courses taken, is important. However, as discussed earlier, success in these classes does not guarantee success as a teacher of mathematics. Success in coursework does not always require a deep conceptual understanding of the mathematics in the course. The example of Ms. Daniels (Borko, Eisenhart, Brown, Underhill, Jones, & Agard, 1992) exemplifies this problem and demonstrates the need for deep content knowledge. As Ms. Daniels struggled to provide a conceptual and concrete explanation of division of fractions, her lack of conceptual understanding prevented this from happening. As the authors suggest, more course work is not the solution to Ms. Daniels' lack of knowledge. The solution is for teachers to have different kinds of experiences in their mathematics courses; experiences that differ from what is traditionally provided in mathematics classes. Simple rote memory and testing of skills and procedures should be replaced by authentic problem-solving and assessment that examines conceptual understanding. If Ms. Daniels had been asked why and how in her mathematics training, she might have developed the understanding she needed to answer those questions when her students asked.

While many exciting materials and reform-minded curricula have been developed for teacher use, these resources do not replace the need for changes in teacher content knowledge. Sherin and Gamoran (2002) demonstrate how teachers with incomplete content knowledge modify reform-minded lessons and materials to match their understanding of the content. Thus, even though the materials approach content in ways consistent with the *Principles and Standards* (2000), the manner in which teachers use the materials may prevent students from developing their own conceptual understanding. Teachers use new textbooks with their old beliefs about teaching mathematics intact, limiting the impact of the materials (Price & Ball, 1997). This implies that new curriculum materials alone will not fix the problem of a lack of content knowledge. Only by providing teachers with opportunities to transform their procedural understanding of mathematics into conceptual understanding will teacher's mathematical knowledge be sufficiently flexible to deal with student exploration and questions—the hallmarks of the reform classroom.

Not only do teachers need to know how to do the mathematics, but they must also understand the culture of mathematics and what constitutes a mathematical argument. Shulman (1987) states that teachers “must understand the structures of subject matter, the principles of conceptual organization, and the principles of inquiry…” (p. 9). This knowledge is necessary, according to Shulman, for mathematics teachers to be able to identify the important concepts and skills and to understand how new ideas are evaluated. Given the goal of the *Principles and Standards* (NCTM, 2000) to create mathematical communities, teachers must understand how mathematics and mathematical culture operates before they can recreate that environment in their own classrooms.

While almost any person on the street would agree that teachers who teach mathematics should know how to do mathematics, not everyone agrees on what mathematics those teachers should be able to do. NCTM distinguishes between the mathematics that mathematicians do, the mathematics that secondary teachers learn in their content courses, and the mathematics that is done in schools. Ball (2000) discusses the common practice of having elementary education majors study the mathematics they will be teaching. However, she points out that this list of required knowledge has often been driven by existing school curriculums, which are not of a reform nature. Therefore, these teachers may not be studying the content important for student learning in a reform setting. Ball suggests that instead of preparing teachers for the content they might encounter, we need to “uncover what teachers need to know and what they need to be sensitive to regarding content to teach well” (p. 244). Ball opens the idea that there may be some fundamental concepts about “equivalence, similarity, and even isomorphism” (p.

244) that are essential if teachers are going to have the necessary content knowledge and flexibility of that knowledge which allows for good teaching. While the exact content that teachers need is still an area ripe for research, the fact that teachers need better forms of content knowledge than has been experienced in the past is well established.

Understanding How Students Learn

Along with teachers being able to do mathematics in flexible ways, teachers need to understand how students learn. This is a vital component in the mathematics reform movement. The *Principles and Standards* (2000) are built on constructivist theories of learning in which students make sense of the mathematics by assimilating information into their prior knowledge. Clearly, understanding developmental and cognitive theories of learning plays an important role in understanding how students learn. Therefore, teachers must learn about the relevant theories of learning and understand how those theories apply to students' learning of mathematics. Part of this understanding is recognizing that students come to the classroom with "preconceptions about how the world works" (NRC, 2000, p. 14). In order to empower students for learning, teachers need knowledge about how students connect these preconceptions to the mathematical topics at hand.

What about student learning should teachers know? The National Research Council (2000) summarized the key findings of research about student learning: (a) students enter school with preconceptions of how the world works and learning must be connected to those preconceptions; (b) students need to understand mathematics factually and conceptually and that knowledge must be organized in a way that facilitates application; and (c) metacognitive and self-regulative strategies should be taught to empower students. To understand the preconceptions that students have, teachers have to carefully listen to students and understand how the students have constructed their understanding (Ball, 1997b). This will also aid teachers in assessing how closely what the students are learning matches the goals the teacher has for student learning (Hawley, & Valli, 1999). Understanding these preconceptions and subsequent development requires that teachers have “a grasp of the growth and development of students’ thinking about these concepts” (NRC, 2000, p. 20). This knowledge is not necessarily intuitive and must be shared with teachers in some formal way, rather than assuming that teachers will develop this knowledge by experience. Some ideas for making this knowledge explicit consist of using videotapes of classrooms (Crockett, 2002; Kinach, 2002) and actual student work (Crockett, 2002). Through discussions, preservice and inservice teachers can both benefit from using these resources to examine student thinking and teachers' assumptions about that thinking.

In her discussion of understanding how students learn, Ball (1997a) proposes knowledge of students as a “core domain of professional knowledge” (p. 732). She includes in this core domain knowledge of the research on student learning and the research on pedagogical content knowledge. Ball also stresses that teachers must have knowledge about the “effects of students’ age, abilities, interests, and experiences on learning” and “the influence of students’ linguistic, ethnic, racial, and socioeconomic backgrounds” (p. 732). These elements indicate the situated nature of learning. Not only do the beliefs that teachers hold impact what goes on in the classroom, but the beliefs of the students and the past experiences of the students also greatly impact how learning happens. An examination of these two elements in Ball's article reveals the role that the learner plays in the learning process. The teacher may have constructed knowledge and understanding of the content personally. However, given different preconceptions, students may encounter the teacher's selected tasks or representations in an unintended way. If a teacher does not anticipate misconceptions and does not check to confirm what students have learned, students can leave the classroom with a misconception about fractions and their relationships. Obviously, it is possible for teachers to know what the research says about student learning, and then to ignore the disconfirming examples that students present in the real classroom. Teachers may also have information about a students' background or prior knowledge, but choose to ignore the impact those life experiences have on the students' interpretation of the mathematics occurring in the classroom. Therefore, acknowledging that these two themes determine a distinct category of knowledge serves the purpose of making explicit the active and personal role that students should hold in the reform classroom.

Knowledge of General and Content Specific Pedagogy

NCTM categorizes general pedagogical knowledge along with pedagogical content knowledge. These ideas are also closely related to content knowledge. The differences between the three warrant their separation into distinct categories. Having already discussed content knowledge, I will now address general pedagogical and pedagogical content knowledge separately.

General Pedagogical Knowledge

Shulman (1987) defines general pedagogical knowledge as paying special attention to “those broad principles and strategies of classroom management and organization that appear to transcend subject matter” (p. 8). Early in teaching, many teachers have concerns about survival. In their study, Gilles, McCart Cramer, and Hwang (2001) examined interview data collected from first year teachers in November of each year for five years. Each of the five groups of first year teachers expressed concerns about survival in first year of teaching: concerns about how they were doing as teachers, concerns about discipline and management, school and organization demands, and concerns connected to students. Many of the concerns listed by the teachers in this study were ideas identified in the process-product research. This earlier era of educational research, labeled process-product research, added much to literature about what effective teachers do. This research was concerned with “teacher behavior and its apparent effects on pupils” (Nuthall & Alton-Lee, 1990, p. 548). Overall, that era of educational research led to much valuable knowledge about the workings of efficient, organized, and well-conducted classrooms and has provided specific steps for how teachers can accomplish this goal (Nuthall & Alton-Lee, 1990). Clearly, being able to organize and efficiently run a classroom is one aspect of pedagogical knowledge that is well researched.

In her description of the different orientations of teacher preparation, Feiman-Nemser (1990) suggested five categories of conceptual orientations for teacher education: academic, practical, technological, personal, and critical/social. Typically, the practical orientation provides opportunities for teachers to learn about general pedagogical methods, including management and teaching strategies. Often, the other orientations neglect this knowledge, having an underlying assumption that these skills will be learned through experience. Feiman-Nemser recommends that programs incorporate elements of each orientation, rather than disregarding any one aspect. The joining of theory and practice is accomplished through the incorporation of the vast amounts of research on effective classrooms into inservice experiences along with the use of authentic artifacts from actual classrooms (Smith, 2001).

Content Specific Pedagogical Knowledge

Shulman is credited with first naming the entity we now call pedagogical content knowledge. Shulman (1987) defined pedagogical content knowledge as “that special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding” (p. 8). It is this category of knowledge that pulls together the content knowledge and the practices of teaching. However, as Shulman (1986) discusses, this aspect of teaching is vital to the reform era. By acknowledging that students arrive in the classroom with already held conceptions and beliefs, teachers must have tools to deal with how the new content knowledge interacts with those ideas. Pedagogical content knowledge is that tool. With many believing that teachers gain this knowledge purely through experience, content specific pedagogical knowledge had been long ignored (Ball, 2000). Shulman has made us aware that this part of the knowledge base should be addressed early in a teacher’s career.

It is important to stress the relationship between pedagogical content knowledge and content knowledge. In his study of prospective secondary mathematics teachers, Even (1993) examined teachers' understanding of functions and found that the preservice teachers lacked complete understanding of functions and were unable to explain functions except as formulas. This incomplete understanding of functions prevented the preservice teachers from being able to create a modern understanding of functions for their students. This study is offered as one example of the importance of content knowledge in developing pedagogical content knowledge.

Lest the reader think that content knowledge alone is sufficient for teaching, Ball (2000) explains how content knowledge and pedagogical content knowledge differ. Just knowing how to do the mathematics does not mean that the teacher will understand what mathematics is difficult for students to learn or which representations are best for introducing a new concept. In the example of the concept of functions, lacking a personal understanding of the concept clearly prevented adequate teaching. On the other hand, possessing complete knowledge of functions would not necessarily lead to helping students understand functions as more than equations. The close relationship between content knowledge, general pedagogical knowledge, and pedagogical content knowledge explains the difficulty in assigning responsibility for the teaching of each, but also stresses the importance of understanding their differences. As Ball states, pedagogical content knowledge "is not something a mathematician would necessarily have, but neither would it be familiar to a high school social studies teacher. It is quite clearly mathematical yet formulated around the need to make ideas accessible to others" (p. 245).

Pedagogical content knowledge is another area in which teachers are often expected to pick up knowledge through experience alone. Kinach (2002) proposed that a more conscientious effort be made to teach pedagogical content knowledge to teachers. Based on "the tension of paradox" (p. 65), this model creates a tension between what preservice teachers expect teaching to be about, and what they actually experience it to be. The model begins with initial readings, followed by videotape viewing and discussion. This is followed by a set of tasks designed to challenge the preservice teachers' procedural view of mathematics. The teachers are asked to explain addition of integers and are then asked how their explanation would help students differentiate between adding a negative number and subtracting a positive number. After reflecting on this challenge, the students are asked to use algebra tiles to explain the concept, followed by another opportunity to reflect. Because this task is done in collaboration with other preservice teachers, each person's explanation is challenged. The awareness that the proffered explanation lacks completeness and the opportunity to revise their thinking, offers preservice teachers the chance to grow before operating on their own. The students in Kinach's work demonstrate that knowing mathematics and being able to help others understand mathematics are very different skills and more efforts need to be taken during content classes and other preservice methods courses to help new teachers develop this talent.

Knowledge of Self as Teacher

The *Principles and Standards* (NCTM, 2000) state that teachers must have an understanding of their personal assumptions and biases about mathematics, teaching, and about students, while maintaining a willingness to investigate new ideas about mathematics and mathematics teaching. To accomplish this, teachers must understand their held beliefs but still be able to make changes in those beliefs. While Borko and Putnam (1995) do not list beliefs as one of their categories in the knowledge base for teaching, they do stress the importance of prior knowledge and experience in shaping future learning for teachers. They state that teachers preexisting knowledge and beliefs must be examined. This examination should happen through reflection and collaborative activities that allow teachers time to challenge their current thinking. Citing the vast research base on Cognitively Guided Instruction, Franke, Fennema, and Carpenter (1997) explain how teachers' use of new materials and resources is influenced by currently held beliefs. As teachers interact with new materials, the resulting interpretations and implementations of those materials are a consequence of the materials being filtered through the teachers' beliefs about what and how mathematics should be taught. The authors suggest that teachers must gain an awareness of how their beliefs are impacting their choices before they have a complete awareness of who they are as teachers. Therefore, if real change is going to happen, many of the beliefs held by teachers must be challenged.

Teachers undergo changes in their beliefs and practices in different ways. In her analysis of the reflective practices of three elementary teachers, Senger (1998-1999) noticed that teachers may be in one of three places: (a) They may use reform language but evidence no reform practices in the classroom; (b) they may try new practices without having considered the consequences of such practices; or (c) they may appear to ignore reform practices to which they were introduced. In her discussion of one of the case studies, Senger explained how the teacher's involvement with the "new math" era of the 60's was negatively impacting the teacher's willingness to try any new methods in the classroom, until those methods could be proven to work. Another teacher used the language of reform mathematics teaching in the conversations with the researcher, but then did not evidence any such efforts in the classroom. This teacher may have been "trying on" the new ideas and using verbal discussion to understand how these ideas would impact the classroom. I use these examples to show how complex teachers' beliefs can be and how difficult unpacking and examining those beliefs is in reality. Teachers' beliefs are often in conflict with reform efforts and therefore need to be challenged. Finding effective ways of uncovering those beliefs, and understanding the interplay between conflicting beliefs and transitioning beliefs is much more complex and not easily done.

Summary of Teachers' Knowledge

A final category of knowledge for teachers is the knowledge gained through experience, called practical knowledge (Carter, 1990). Almost every experienced teacher attributes much, if not all, of their knowledge to something we might call "trial by fire." Carter (1990), drawing from the expert-novice research, discusses *tacit* knowledge, knowledge that is developed from and through experience. Some of this tacit knowledge is practical knowledge. Carter defines practical knowledge as "the knowledge teachers have of classroom situations and the practical dilemmas they face in carrying out purposeful action in these settings" (p. 299). This knowledge tends to be more personal and situational than is pedagogical content knowledge, meaning that the knowledge was constructed under specific contextual settings rather than being based in formal theory. Practical knowledge plays a large role in how teachers respond to situations, plan lessons, and generally conduct their lives as teachers. While this category of knowledge has often been devalued, current efforts are using this knowledge to induce change. One example is the learning community demonstrated in Gamoran (2003). These learning communities used actual student work from the teachers' classrooms to generate discussion and research about student thinking. The collaborative efforts of teachers looking at their own students in their own classrooms allowed for interaction between the practical and theoretical realms. Cochran-Smith and Lytle (1993) suggest that teachers doing research in their own classrooms, in collaboration with others, is a vital effort needed to better understand how the practical knowledge of teachers can inform educational theory. Clearly, the practical knowledge of teachers plays an important role in the education process.

Van Driel, Beijaard, and Verloop (2001) summarized teachers' practical knowledge. They concluded that practical knowledge is gained through personal experiences which are situated in particular classrooms that are centered around a specific content area. It is also mostly tacit, meaning that teachers are more used to *doing* it than *talking* about it. And finally, practical knowledge is highly integrated with formal knowledge, everyday knowledge, values, and beliefs. Given this description, it appears that most of teachers' practical knowledge develops through experiential learning in specific settings. This situated nature may make transfer of knowledge difficult, providing a partial explanation as to why preservice teachers often have trouble applying knowledge from their college courses in the classroom (Borko, et. al., 2000). Because of the situated nature of practical knowledge and the strong connection to beliefs and personal experience, making changes in this kind of knowledge can be very difficult, even when a teacher wants to change. Multiple methods of approaching practical knowledge are necessary to bring about change (Van Driel, Beijaard, and Verloop, 2001). These multiple methods include long-term professional development situations that make use of teacher networks, peer coaching, collaborative action research, and narrative vignettes or cases studies for teachers' to examine and upon which to reflect.

The knowledge base required to implement the ideas embedded in the *Principles and Standards* (NCTM, 2000) is vast and varied. The knowledge base has six categories which are distinct but closely related. Teachers first need to have reform experiences in which they learn new mathematical content using reform methods. Teachers need to know the mathematics they are teaching in a complete and flexible way. They also have to understand how the content in their courses connects to the bigger mathematical picture and to other mathematics courses the students will take. Teachers must have vast knowledge about how students learn. Additionally, teachers must understand how the students sitting in the teachers' own classrooms learn. This specific knowledge of the students will help teachers implement the appropriate general pedagogical knowledge and content specific pedagogical knowledge. As these pieces come together, teachers must begin to understand how their personal beliefs drive their classroom practices and interactions with students, which leads to knowledge of self as teacher. Finally, through experience, teachers gain practical knowledge which interacts with the theory behind the content knowledge, pedagogy, and personal beliefs.

Because this knowledge is built through experience and formal instruction, teachers must be provided with appropriate experiences during their formal instruction. The mathematics classes that teachers take should implement the same teaching methods that teachers will implement. This includes preservice and inservice mathematics classes. Connections between theory and practice must be made for teachers during their preservice and inservice experiences, to encourage teachers to grow in their knowledge about student learning. Teachers must also be challenged to examine the beliefs underlying the choices they make in the classroom. This challenge should begin in their preservice experiences.

Teacher Change

Teachers change in many ways. As Jackson (1992) describes, teachers have experiences that change who they are. They teach longer and become more comfortable with the textbook they use. They manage the classroom differently over time. They gain new skills for teaching their content. They sometimes gain more authority within the school system. They earn more money, and might change grade levels or switch courses that they teach. Some teachers become more compassionate; some become more cynical. Some teachers lose their enthusiasm for teaching; others just develop more grey hair. All of these items can be categorized as teacher change, and all may point to life experiences that influence the classroom in subtle or not so subtle ways. This study will focus on what Jackson calls teacher development, “the subclass of changes that are desirable and positive in quality as opposed to negative” (p. 63). In this case, desirable and positive mean changes that move the classroom closer to the vision embodied in the *Principles and Standards* (NCTM, 2000). Often these changes are demonstrated through changes in teaching practices, which are easily observed and documented. However, teachers sometimes start thinking changes before they enact changes, as evidenced through their discussions (Senger, 1998-1999). Therefore, for this study, teacher change will also include a shift in thinking or beliefs. A subtle note becomes apparent here. Many of the changing experiences that teachers have occur randomly and not as a concerted effort toward change. Although those experiences are valuable and worth studying, the focus here is concerned with organized and intentional experiences and their impact on teacher change.

Understanding teacher change requires first understanding the context in which teacher development occurs. Feiman-Nemser (2001) offers a view of teacher development that perceives development as an ongoing process beginning with preservice education and continuing on throughout a teacher’s career. This view contrasts with the more traditional view in which teacher development occurs in chunks: preservice, first year, continuing education. The traditional view tends to segregate teacher learning, making it difficult for teachers to connect the theoretical knowledge often gained in preservice classes to the practical knowledge gained through experience. However, most of the current literature was written within the traditional view of teacher development, and addresses preservice education as a separate entity from inservice education. While this view is changing (Darling-Hammond & Sykes, 1999), the long-term teacher professional development programs that have been implemented and analyzed have not been attempted in this context. Therefore, the reader should understand that this review of literature will examine issues surrounding inservice teacher development in an era that did not necessarily think of inservice and preservice development as being parts of the same whole. For this reason, and because the teachers in this study were already practicing teachers with at least one year teaching experience, this review will examine only literature connected to practicing teachers and will not include information specific to preservice teaching.

Teacher change is not developmental in the strictest sense, but is orderly (Goldsmith & Shifter, 1997). This orderliness means that some parts of the change process are predictable. However, Goldsmith and Shifter warn that this predictability only appears when a teacher’s current profile is taken into consideration. They provide examples of an elementary teacher and a secondary teacher. The elementary teacher participated in professional development because of a desire to improve what the teacher perceives to be a weak area. This teacher’s successes in other content areas created an awareness of better ways of teaching, but the teacher felt unable to transfer those kinds of practices into the mathematics classroom due to lack of mathematical knowledge. On the other hand, the secondary teacher had a well-developed understanding of mathematics, but felt weak in interpreting what students were actually taking away from the classroom. Goldsmith and Shifter explain that these two teachers would not respond to the same professional development program in the same way. This is because their needs differed. However, other teachers who enter the program seeking to fill a weakness in content knowledge may go through a process of change similar to the one experienced by the elementary teacher. Likewise, teachers unsure of how to assess students' understanding may go through developmental changes more like those of the secondary teacher in the example. Therefore, understanding the context in which the teacher is operating is an important aspect of teacher change, and contributes to likely patterns to be found in teacher change.

Although these two teachers had different needs resulting in different kinds of changes, these teachers might have experienced some similarities as they change. In his review of recent research regarding the Concerns Based Adoption Model, Anderson (1997) stresses that this model is still relevant to today's reform efforts. The Concerns Based Adoption Model examines the Stages of Concern, Levels of Use, and Innovation Configurations as individuals undergo change. The Stages of Concern seem particularly relevant to understanding how teachers are experiencing the changes through which they are navigating. The Stages of Concern "describes the feelings and motivations a teacher might have about a change in curriculum and /or instructional practices at different points in its implementation" (p. 334). Not all teachers go through every stage, but they do generally progress through these stages: awareness, informational, personal, management, consequence, collaboration, and refocusing. The vast amount of research reviewed by Anderson indicates that the theory is a valid way of examining some of the factors involved in teacher change. What we can take away from this vast body of research is the fact that teachers' concerns when implementing innovations in the classroom progress through fairly clear stages and that professional development programs should help teachers address these concerns and promote movement through the stages.

Looking at the specific stages in the Concerns Based Adoption Model, one might notice that the intensity of concern begins rather weak during the awareness and informational stages, intensifies during the personal, management, and consequence stages, and could be perceived to decrease again as the teacher collaborates with others. The collaboration with others implies a comfort level with the innovation that was not apparent during the personal and management stages. This idea of changing intensity is supported by Maverech's (1995) U-shaped professional development model. Mevarech claims that professional development is not linear but rather has a U-shaped curve, with a negative slope representing decline in performance and attitudes followed by an upward slope, representing increased knowledge of pedagogy and content. When trying any new method in the classroom, even an experienced teacher goes through the first year problems again, connected to the new method. However, after more experience with the method, the teacher then regains lost ground and has a new method to use. The reason for this downward decline may be the conflict between old knowledge held by the teacher and the new knowledge required for the method or innovation the teacher is trying. As a teacher survives this shift in knowledge, the teacher moves on to conceptual understanding of the innovation in use. The implications of this U-curve to professional development are that teachers need to be given a way to deal with the downward decline, which is often unexpected by the teacher.

Undergoing changes in teaching practices is an emotional adventure (Hargreaves, 1995). The downward decline discussed by Maverech describes the emotional rollercoaster on which teachers ride when invoking change. Trying new ideas in the classroom is unpredictable and can cause turbulence and excitement for teachers (Hargreaves, 1995). As veteran teachers' long-held beliefs are challenged, emotional responses are invoked (Hyde, 1992). As teachers revisit feelings of a first year teacher, they may feel frustrated, helpless, elated, isolated, confused, and vulnerable. These emotional responses need to be dealt with to encourage continued risk-taking on the part of the teachers. Clearly, teacher change is not purely an analytical rational endeavor. It is, instead, an emotionally challenging experience.

Traditional Experiences in Professional Development

So far, the working definition of teacher change in this study is the change in teaching practices, teachers' thinking processes, or teachers' beliefs that are the result of thoughtful, planned experiences that intend to impact practicing teachers. Change is developmental in that the concerns teachers have seem to be fairly consistent, but teachers in different circumstances have different needs. Historically, professional development for teachers has been less personally oriented, and more driven by top-down methods. As described by Clark (1992), professional development often has a negative connotation for teachers because of past practices. Frequently, professional development has meant "a process done to teachers; that teachers need to be forced into developing; that teachers have deficits in knowledge and skill that can be fixed by training and that teachers are pretty much alike" (Clark, 1992, p. 75). Loucks-Horsley (1997) describes these traditional experiences as “one shot,” “’good bye, God bless you’ workshops,” and “’talk at me’ conferences” (p. 134). These kinds of workshops resulted in short-term situations where teachers were shown how to do a skill in which someone, usually not the teachers, had decided that the teachers were deficient. Teachers left these workshops to return to their classrooms and supposedly implement the new skill. No consideration was given to the differences among teachers, students, or classroom situations. Much of the traditional professional development opportunities focused on a narrow aspect of skills for effective teaching. No time was devoted to helping teachers develop flexibility in listening to their students, understanding students’ prior knowledge, nor in developing flexibility in their own beliefs about teaching, all of which are required for teachers to learn how to provide opportunities for students to learn (NCTM, 2003). The kinds of changes being asked of teachers are not just skill oriented. In addition to asking teachers to add to their skills, the current reform movement is asking teachers to make changes that are transformative, changing the teacher (Smith, 2001).

Jackson (1992) categorizes these kinds of traditional experiences as helping teachers develop by telling them how or what to teach. During what is now termed the process-product era of educational research, most of the focus was on effective classroom management. Applying the working definition of teacher change to the process-product era might have meant teachers learning a list of skills such as presenting new material in small steps, providing clear instructions, using questioning to check for student understanding, and providing practice for students on new skills (Rosenshine, 1986). Providing teacher development by telling teachers how to use these skills may have been sufficient, even effective, for these kinds of generic pedagogical skills. However, these methods of teacher-training are no longer adequate in the current reform era.

The problem with the traditional methods in the new reform era arises from the great differences between the model of teaching mathematics in the past and the models of teaching necessary for accomplishing the vision of the *Principles and Standards* (NCTM, 2000). Cooney and Shealy (1997) describe how the changing view of mathematical activity within the mathematics community combine with shifts in thinking about the nature of mathematics to create necessary changes in instructional issues. Teachers, who view mathematics as a fixed and well defined body of knowledge, are being asked to embrace constructivist methods of teaching, which require greater attention to students’ formation of mathematical concepts. Teachers are being asked to provide opportunities for students to learn (NCTM, 2003). These opportunities required for students to learn for understanding are fundamentally different from the experiences through which the teachers learned mathematics. “Because this picture is a significant departure from traditional instruction, teachers cannot realize these new images by simply adjusting a bit of practice here and there or by importing a new teaching technique or curriculum package” (Goldsmith & Schifter, 1997, p. 20). Teachers cannot be simply told how to change the way they view mathematics and they obviously cannot change their background knowledge. But, without these changes, their classrooms cannot become focused on students’ understanding of mathematics. Therefore, different methods for professional development are needed.

Professional Development for Change

Teachers must provide opportunities for students to learn (Heibert, 2003). This necessitates professional development experiences that offer teachers opportunities to learn. Being able to teach in reform ways means finding opportunities to learn skills of effective teaching, developing as a flexible and sensitive teacher, and having a working environment that is conducive to teaching and continuous improvement (Hargreaves & Fullan, 1992). These kinds of opportunities not only change teachers' practice, but also change the teacher (Hargreaves & Fullan, 1992). Therefore, the goals for professional development of mathematics teachers must include providing teachers with necessary experiences and knowledge about teaching mathematics, support and opportunities to develop flexible ways of thinking as a teacher, and assistance in operating under and influencing their work environment. The discussion of these goals will take place on two levels. First, some guiding principles for effective professional development will be discussed. The second level of examination will be an exploration of specific ways in which these principles are being implemented.

Principles for Effective Professional Development

In order to accomplish the goals of necessary experiences, knowledge, flexibility, and assistance, Loucks-Horsley (1997) proffers a list of principles for effective professional development. The first principle is that "fundamental change (learning) occurs over time, through active engagement with ideas, understandings, and real-life experiences" (p. 134). The placement of this principle in the first position on the list seems important. The fact that change takes time is echoed by others (Borko & Putnam, 1996; Feiman-Nemser, 2001; Little, 1999; Thompson, 1999), and was an often missing component of earlier efforts. The research studies examined later in this paper all lasted at least one year, with some extending over two or three year periods. This is considerably longer than the one day or one afternoon workshops that school districts often provide their teachers.

The second principle offered by Loucks-Horsley addresses the manner in which teachers experience changes. Teachers go through predictable stages as they implement changes in their teaching practices. These stages include aspects of the teachers' emotions, knowledge about the new practice, and comfort level. Earlier in this paper, the developmental stages through which teachers go as they try to incorporate new ideas into their classrooms were discussed. The emotional aspect of change warrants a further look here. While this aspect follows a predictable pattern, as demonstrated in the Concerns Based Adoption Model, those emotions have often been ignored in professional development experiences. As noted earlier, undergoing changes in teaching practices also changes the teacher (Hargreaves & Fullan, 1992), but most professional development opportunities neglect the emotions of teachers (Hargreaves, 1995; Weissglass, 1994). Changing of self and the environment in which one teaches can be an emotional voyage for teachers. Hargreaves, (1995) points out that the dominant tones of traditional development opportunities tended to be masculine in nature: rational, calculative, and managerial. This practice is still pervasive even in reform-minded efforts. Although teachers are asked to reflect on their practices, this reflection is often structured around thinking, analyzing, and inquiring, and not about feeling or intuiting (Hargreaves, 1995).

Weissglass (1994) urges the incorporation of the emotional needs of teachers into professional development plans. In order to make teachers more comfortable with reform, teachers should share their concerns along with sharing ideas. These concerns may deal with the semantics of implementation, as demonstrated in the Concerns Based Adoption Model (Anderson, 1997), or more personal feelings around the implementation process. Weissglass warns that ignoring the emotional aspects of change and the feelings that teachers experience, allows the creation of yet another obstacle to successful change. Therefore, Loucks-Horsley's inclusion of emotions is a principle worth noting.

The third principle for effective professional development reminds professional development providers to use what is known about effective teaching (Loucks-Horsley, 1997). Whatever the structure of development programs, they should be centered on the teachers needs, centered around current knowledge and research, assessment centered in that they provide chances for teachers to experiment with and evaluate ideas, and centered around the community in which the teacher works (NRC, 2000). These ideas are based in research and have been shown to increase student learning. Therefore, these same ideas should be applied to teachers' experiences to offer them the relevant chances to increase their learning.

In keeping with the need to stay learner-focused, the fourth principle for effective professional development encourages the use of alternative platforms for teacher learning. Instead of restricting development to workshops, courses, and institutes, professional development providers should consider alternatives as avenues for fostering change. Some examples of alternative platforms include individually guided plans, curriculum development, textbook adoption, action research, and connections to larger, systemic improvement programs.

The final principle states, "professional development can only succeed with simultaneous attention to changing the system within which educators work" (Loucks-Horsley, 1997, p. 139). The teacher change cycle proposed in the theoretical framework is partially based on social cognitive theory and recognizes the reactionary relationships between the individual, the environment, and behaviors. A change in the system, or context, in which teachers work is likely to happen as teachers progress through the change cycle. However, as Fullan (1993) noted, this is unlikely to happen until teachers learn to use the skills of goal setting, inquiry, mastery, and collaboration. Helping teachers develop a pattern of change that incorporates those skills is what the new movement in professional development embraces.

Specific Actions for Professional Development

These principles for professional development provide guidelines for those planning programs, but not specific actions. To achieve the vision in the *Principles and Standards* (NCTM, 2000), teachers will have to unlearn much of what they know, and develop new beliefs and knowledge (Thompson & Zeuli, 1999, p. 341). The difficulty has been deciding on the necessary experiences to allow teachers to form new knowledge and beliefs. An examination of the literature on effective professional development for mathematics teachers yields much information about explicit measures that have been used in attempts to follow the guiding principles. These actions fall into six basic categories: teacher thinking, dissonance in beliefs, teachers' context, new skills, support, and reflection. These categories do not fit neatly under individual guiding principles, but rather, tend to fall under more than one principle. Also, the categories themselves, created by the author of this paper, do not always have decisive boundaries, leaving room for some overlap. Therefore, the reader may notice that some activities or measures described could also be placed in additional categories. The intent of this section is to help the reader understand the kinds of measures required to help teachers change. Activities which accomplish more than one goal match the vision of reform intentions, in which the connections within the content, between school and real life, within the individual, and between persons involved are emphasized.

Activities directed at encouraging teacher change must allow teachers to think. Teachers need time and opportunity. Thompson and Zeuli (1999) highlight the need for sufficient time. Sufficient time means that the involvement in a program needs to be long enough for teachers to build rapport with others, have time to try out ideas, and time to break down and rebuild practices (House, 1994). This kind of time is measured in months and years, rather than hours. As well, sufficient time can also mean having enough time to engage in thinking about mathematical problems, to struggle with and through difficult tasks. This definition of time may mean that many hours and days during a program are devoted to the teachers experiencing authentic problem solving.

In addition to time, teachers need to be in an environment that encourages their thinking. This means that professional development programs must utilize what is known about adult learners so that appropriate environments can be created (Loucks-Horsley, 1997; NRC, 2000). Allowing teachers to think in reform ways also means providing teachers opportunities in which they have to think about mathematics in different ways. NCTM (1991) has listed as one of its principles for professional development the provision of good mathematical experiences for teachers. These good mathematical experiences involve the teachers in developing and applying conceptual understandings of mathematical ideas. Teacher thinking must be the first consideration in the choice of activities and structure. Incorporating teacher thinking necessitates designing the program with adequate time constraints, utilizing information about how adults think and learn, and providing appropriately challenging mathematical activities built around conceptual understanding.

The second category of creating dissonance in teachers' beliefs is often discussed but may be more difficult to accomplish than the first category. As Thompson and Zeuli (1999) discuss, teachers can often appear to be doing the right thing, but still be completely missing the intent of reform. This occurs when the teacher's beliefs conflict with reform ideas (Ball, 1996). NCTM (1991) recommends providing experiences that cause teachers to revise their assumptions about the nature of mathematics and the nature of student learning. To challenge ideas on the nature of mathematics, teachers have to see mathematics as a growing and changing body of knowledge that is discovered and created within a social community (NRC, 2000). They also have to have experiences with different kinds of students in different settings where students' thinking is made explicit. Many teachers will also have to change their view of authority (Cooney & Shealy, 1997). They often see others as experts in mathematics, but fail to see themselves as one of the experts. The textbook, professors, school administrators, parents, or proclamations from professional organizations are all valuable resources, but the teacher also needs to see self as a valuable resource. Unless the teacher comes to a view of self as authority, decisions about the classroom are made by outside sources without consideration for the needs of the students. The beliefs that teachers hold are numerous and complicated. Activities that bring these beliefs to the surface, allowing them to be examined in productive ways, must become a fundamental part of the professional development process.

The context in which a teacher teaches, or the working environment, must be accounted for when planning professional development programs (Cohen & Ball, 2001; Guskey, 1995). The idea of situative perspective explains why the teacher's work environment must be an integral piece of professional development. According to Putnam and Borko (2000), "how a person learns a particular set of knowledge and skills, and the situation in which a person learns, become a fundamental part of what is learned" (p. 4). The situation in which a teacher learns to teach is the classroom and, thus, becomes integrated into what the teacher learns. Guskey (1995) contends that what constitutes successful professional development for one school may not be so for another school, because of the differences between the cultures of the schools. He warns that by looking at only the commonalities of successful development endeavors and reducing future efforts to those commonalities, that what was an essential component for a given school may be ignored. Reformers must search for "the optimal mix" of strategies and approaches that work best for a specific situation. Jones, et al. (1997) elaborate on the school climate. The participants in a school include the teacher, students, students' parents, other teachers in the building, administrators, staff, and the community in which the school sits. All of these people have expectations about what should happen in the classroom and, by their participation, contribute to the norms that exist inside the school and classroom. As Guskey warns, ignoring the established norms of the entire set of participants is likely to result in failed attempts at change.

The working environment, or context, is not limited to just the building in which the teacher teaches. According to Jones, et al. (1997), along with school norms and expectation, context includes the way policy is interpreted, influencing participants' perspectives on mathematics. The school is situated inside a local district which is located inside a specific state. How the district and state position themselves regarding changes also shapes the individual classroom. As for conceptions of mathematics, each person involved in the classroom, has a personal conception of mathematics. This group of people includes the students, their parents, the teacher, other school personnel, school administration, state officials, and curriculum material producers. As these individuals interact with or try to understand proposed changes in mathematics teaching, their reactions are guided by their conception of mathematics. Therefore, a necessary part of professional development should be helping teachers understand the stance of their local school district and state. Time should be spent dissecting state and national recommendations about school mathematics.

While the preceding views of context encompass communities of people, context also includes the individual classroom and individual students. Artzt and Armour-Thomas (2002) describe the learning environment as "the conditions under which the teaching-learning process unfolds in the classroom" (p. 14). The teacher plays a great part in establishing the learning environment, and it is therefore reasonable to agree that the teacher has some power in changing the learning environment. However, professional development opportunities must deal with the fact that different teachers create different kinds of context in their classrooms for many different reasons. Traditional methods of professional development either ignored this fact, or suggested that the use of a single method would transform these very different classrooms into similar beings. Artz and Armour-Thomas, along with NCTM's *Principles and Standards* (2000) suggest that differences in learning environments are acceptable, even desirable. Professional development should embrace these differences and help teachers capitalize on the individual strengths of their personally created situations.

Teachers still need skills to teach. Addressing general and content specific pedagogy must still be important parts of professional development (Shulman, 1986). However, a shift in thinking about these skills is seen in the literature. These skills are now seen as being connected to the students in the teachers' classroom (NCTM, 2003; Sykes, 1999; Thompson and Zeuli, 1999). Crockett (2002) recommends the use of actual student artifacts in analyzing students' thinking and understanding. Teachers need to learn to listen to student thinking (Ball, 1996), which means the use of videotaped episodes of teaching becomes valuable. However, as teachers learn these new skills connected to understanding student learning, they must also be given time to practice these skills in their own classrooms, be provided with a forum for discussing the intricacies of implementation, and have access to support for trying and modifying these ideas (Loucks-Horsley, 1997).

Providing support and continued help for teachers undergoing change is another important piece of professional development programs (Loucks-Horsley, 1997; Thompson & Zeuli, 1999). A collaborative environment supports experimentation and risk taking, which are necessary for successful change (Loucks-Horsley, 1997). In her discussion of teachers working to reform their teaching, which she calls “teaching against the grain”, Cochran-Smith (1991) notes that these teachers often have to work harder to prove to others they are competent at the traditional skills along with trying to become competent at new skills. Working in a collaborative environment with other veteran and beginning teachers can provide the support needed to get through the extra hurdles. Support can be provided by other teachers in the same program or school (Manouchehri, 2002; Smylie, 1995). Teachers can also receive support from university faculty through the use of action research methods (Cochran-Smith, 1995). Smylie (1995) recommends that administrators in schools also become sources of support for teachers undergoing change efforts. The idea of using a community during change endeavors can extend beyond these more traditional ideas to include parents, preservice teachers, community members, and students (Frykholm, 1998; Oakes, Franke, Quartz, and Rogers, 2002). Again, support requires time. Whoever is providing support must be available over a long period of time and available at times useful for the teachers.

The final category of actions necessary to promote change during development opportunities involves reflection. Reflection is a way to help teachers make sense of the disequilibrium they experience during the change process (Pape & Costner, 2002). Reflection may take the form of monitoring students’ reactions during the lesson, or assessing the lesson's success after completion (Artzt & Armour-Thomas, 1999). Typical forms of post-lesson reflection include journals, talking to other teachers, and action research (Ball, 1996). Ball (1997) discusses how teachers have to learn to listen to students. This too is a form of reflection; the teacher has to stop and think about how the students are connecting information. As discussed earlier, reflection should be a means to address the emotional aspects of change.

Research on Long Term Professional Development

Many professional development programs have been created to help teachers understand the vision of the *Principles and Standards.* The following section consists of a review of research involving long-term professional development programs which adhere to the principles and activities described in the previous section. The research studies are ordered by the duration of the program. The length of the program seemed to also correspond with the complexity of the program.

Manoucheri (2001) examined collegial interactions of two pairs of middle school mathematics teachers engaged in the implementation of a new, reform oriented textbook. The district granted the teachers one hour release time per week to meet with a partner teacher for planning and discussion of textbook implementation. The teachers were also provided with release time to observe and provide feedback for their partner teacher one time each month. The data in this study were collected over a period of seven months. The task for the pairs was to discuss issues surrounding implementation of the new textbook and to support each other through the process. While the researcher coordinated the process, there was no direct intervention in the interactions between the pairs. Data were collected through observation of pair meetings, attendance at department meetings, feedback and discussions surrounding the partner's observations of each others' classrooms, and informal and semi-structured interviews with each of the four teachers.

The findings of the study indicate that both pairs of teachers provided emotional support for each other and some surface level suggestions about implementing specific activities from the textbook. However, the degree to which the partners impacted each others' practices varied greatly. Julia and Doug eventually reached a point in the year where they challenged each other's thinking and created situations in which the other had to explain their reasoning. This pair was considered successful by the researcher, although the success was largely attributed to Julie's desire to change her own teaching. The other pair, Ben and Gary, did not critique each other's practices. Although Ben and Gary both made private statements to the researcher indicating disagreement with the other's teaching methods, their weekly meetings and monthly observations reflected none of this disagreement. Manoucheri (2001) observes about Ben and Gary, "their observations of one another contributed to the development of stronger beliefs about the appropriateness of what they did in their own classes" (p. 92). This pair reinforced prior knowledge and beliefs instead of creating change in beliefs or knowledge.

The findings of Manoucheri (2001) have important implications for professional development. While the teachers provided emotional support for each other, they were not always able to challenge each other. An outside person could have facilitated creating dissonance in the teachers' thinking. Instead, Ben and Gary exhibited a belief that Ball (1996) describes as believing in the personal style of individual teachers; each teacher has a personal style, which works for that individual. This belief contributes to the pervasive culture of isolation in teachers. Ben and Gary provide excellent examples of this problem. They each believed in their own teaching methods and found problems with the other person's practice, but they did not question the other's practices because of personal style. In their case, challenging this belief in personal style and encouraging change in their teaching practices did not occur because of the lack of outside intervention.

Crockett (2002) addressed a year-long study of teachers involved in an inquiry group, based on the Japanese lesson study. The researcher intended to incorporate open-ended problems, video-teaching vignettes, lesson planning, and analysis of student work into the lesson study to provide the teachers' opportunities for reflection. Analysis of student work was the only component that created discussion leading to disagreements, leading to critical analysis of the teachers' assumptions about teaching mathematics. As happened in Manoucheri's study with Ben and Gary's observations of each other, some activities appeared to provide confirmation for held beliefs and current practices without challenging the teachers' thinking. The open ended problems generated discussion about getting the right answer and blame was placed on students for not using multiple solution methods without any discussion of teaching methods to support students in the creation of multiple solutions. The discussion about videotapes and lesson planning centered on traditional teaching methods and management issues. These conversations did not create any dissonance in beliefs for the teachers. Crockett used these results to discuss the need for activities that expose teachers' beliefs and make them available for discussion.

I would highlight the fact that Crockett's (2002) choice of activities was based in research. Others had found open ended problems, videos of classrooms, and lesson planning to be valuable experiences in bringing about change. However, these activities failed for the group of teachers involved in Crockett's study. Different groups of teachers will respond to different methods. Flexibility in programming and extended contact with the teachers becomes important considering that time may be spent finding the best combination of activities to encourage change for any single group of teachers.

Smith (2000) followed one experienced teacher through the first year of QUASAR (Quantitative Understanding: Amplifying Students Achievement and Reasoning), a middle school reform effort. This teacher was involved in implementing a new curriculum, as were the teachers in Manoucheri (2001). Unlike Manoucheri's study, in which the only support for teachers was provided by partner teachers, support in Smith's study was provided by university personnel through reform mathematics classes, monthly support meetings, and individualized classroom support. Smith's study focused on the dilemmas faced by the teacher during implementation and the catalysts for those dilemmas. The data for this study consisted of the teacher's personal reflections, observations of staff development sessions, classroom observations, pre-observation plans, post-observation reflections, and the teacher's goals. Smith focused on the teacher's concern for ensuring student success. Smith summarizes that the teacher embraced new ideas about teaching and did not initially experience any dissonance with those ideas. When the students struggled with tasks, however, the teacher "reduced the cognitive demands of the task, thus creating simpler subtasks that students could complete more easily” (p. 371). This was a practice consistent with her prior practices and inconsistent with practices encouraged in the program. The teacher had expressed a belief that students needed to struggle to become confident problem solvers. During a staff development session, one of the university personnel challenged the teacher on her need to break down tasks. Smith states that the teacher spent several months trying to reorganize her thinking about this issue. This teacher experienced dissonance by having her conflicting beliefs made explicit. Through a supportive environment, she was able to make some progress in aligning her beliefs and practices. The supportive environment, Smith says, was created through the new curriculum, collaboration with other teachers and university staff, and, interestingly, exposure to new ideas.

Although the studies by Manoucheri (2001) and Crockett (2002) were about professional development programs, the studies themselves did not examine whether or not the program accomplished stated goals. Those studies were focused on the teachers’ experiences during the programs. The next study to be reviewed here is an examination of how well a program accomplished its stated goals. Borko, Davinroy, Bliem, and Cumbo (2000) studied two third-grade teachers involved in a two-year mathematics and literacy program. The findings of this study show that these two teachers made changes in line with the goals of the program. This program, the University of Colorado Assessment Project, was geared toward helping “teachers design and implement classroom-based performance assessments compatible with their [the teachers’] instructional goals-as well as our beliefs about teacher learning” (p. 275). The support for the teachers in this program came from parents and administrators, who agreed to a two-year moratorium on standardized testing, university personnel in weekly meetings with the teaches, and monthly observations of the teachers' classrooms during the second year. Both teachers in this study made changes in their instructional and assessment practices, which the authors attribute to the program design. The teachers' approaches to assessment did change, but not as much as the researchers had hoped. This may be due to the teachers' lack of knowledge and experience with writing reform minded assessments.

Swafford, Jones, Thornton, Stump, and Miller (1999) also examine the success of their program in achieving the program goals. They discuss a 3-year professional development program for middle-grades teachers that intended to bring about change. During each summer, the teachers participated in a four-week content course and 8-hours of research seminars on student cognition. During each school year, the teachers attended six half-day sessions on pedagogical practice. Teacher collaboration and reflection were encouraged through group work on unit development and through individual reflective journals. The quantitative data in this research project consisted of the following for all the participants in the program: knowledge of content tests measured by pre- and post-tests given each summer; instructional practice surveys given at the beginning and end of each intervention; and pre- and post-classroom processes questionnaires. Qualitative data included journals, classroom observations, and interviews for six target teachers. All teachers in the program demonstrated increased content knowledge and changes in instructional practices. One key change resulting from the program was a decrease in the teachers' reliance on textbooks, including less use of textbook publisher created assessments. The authors conclude that the increased content knowledge and collaborative support resulted in a dramatic change in the teachers' perception of themselves as mathematicians and added to the teachers' sense of professional knowledge.

The next study to be discussed uses the program examined in Swafford, et al. (1997) as a framework. Jones, et al. (2000) examine PUMP (Peoria Urban Mathematics Plan), a 3-year professional enhancement program involving 31 middle school and 12 high school mathematics teachers. This program also consisted of three 4-week summer content courses, pedagogical practice seminars during the school year, collaboration with other teachers, and on-site support to increase teachers' knowledge of mathematics, student learning, and pedagogical content knowledge. Specifically, PUMP focused on promoting awareness of equity issues, worthwhile mathematical tasks, student discourse, and student collaborative tasks to accomplish the goals. In their qualitative study of 6 middle school teachers, the researchers used pre- and post-intervention problem solving scores, pre- and post-scores on beliefs surveys, and videotapes of the teachers' classrooms, one from before the program and one at the end of the program. The teachers also provided summaries of those videotaped lessons. Additionally, the researchers included information from the year long instructional plans created by groups of teachers.

While the teachers showed no significant change in beliefs about mathematics, they did show significant changes in their beliefs about enhancing student discourse, teaching strategies, and student problem solving. Through videotape analysis of the six target teachers, the researchers found evidence of change in student discourse and collaboration. Generally, the researchers found that the program had a greater impact on how the teachers established a classroom environment than on the mathematics that was taught or on how the students learned. Most of the teachers did not move to engaging students in mathematical sense making and construction of their own knowledge. These ideas, while serving as foundational for program construction, may not have been explicit enough to change teachers' practices. The ideas that were explicitly addressed, student discourse and student collaborative activities, were significantly changed.

Notice the different findings between two similarly constructed programs. While Swafford, et al. found significant changes in content knowledge, Jones, et al. found significant changes in only portions of the teachers' content knowledge. In Swafford, et al., the teachers changed their beliefs about themselves as mathematicians. The data from the beliefs surveys in Jones, et al. did not support such conclusions. These two studies demonstrate that different groups of teachers are respond differently to the same program. There may have been differences in the school settings that created different needs for the teachers. Differences in the content classes and seminars were also possible. Although based on the same structure, the two programs resulted in different experiences, and thus, different changes for the teachers. The lesson to be taken from the examination of these two studies is that professional development planners should be wary of seeking a formula for development plans. The "one size fits all" mentality of the past will not work in the current era. Professional development providers need to get to know the teachers, and be able to modify the program as the teachers' need change.

Franke, Carpenter, Levi, and Fennema (2001) state that current professional development programs aim to help teachers "come to see themselves as ongoing learners" (p. 658). Franke, et al. calls this creation of ongoing learning "generative change." I would argue that the majority of current professional development programs do not accomplish the goal of creating generative change. The research presented thus far in this paper serves as a representative sample of excellent professional development programs. These programs were reform minded and provided effective development opportunities for the teachers. Because of these programs, teachers moved closer to the vision in the *Principles and Standards* (NCTM, 2000). However, while the providers of those programs may have dreamed about developing ongoing learners, this desire was not made explicit in the design of the programs. As described in the research presented here, these programs tended to focus on "the fidelity of teachers' practices to those specified in the training programs" (Franke, et al., 2001, 658). Franke, et al. intended this description for the traditional kinds of professional development programs, but the observation applies to these reform minded programs. Such programs can fail to make explicit for teachers the skills they needed to continue learning. Teachers need to become agents of change (Fullan, 1993) as well as learning the new, reform-minded teaching skills.

An examination of Franke, et al. (2001) provides the missing ingredient. As part of the Cognitively Guided Instruction (CGI) study, a 3-year longitudinal study of first- through third-grade teachers was conducted. The study in Franke, et al. goes back to those same teachers two years after the program's completion. During the first two years of the CGI program, the teachers participated in workshops, attended meetings with other teachers, and received support in their classrooms from university personnel. During the third year, university personnel visited the teachers' classrooms on a regular basis and interviewed the teachers. This was more a function of data collection rather than serving as support for the teachers. The study includes interview data, and self-reports during the fourth year to “examine the characteristics of teachers who had learned since the end of the professional development” (p. 659). To accomplish this task, the researchers first categorized the teachers according to their level of engagement with students’ mathematical thinking. This categorization was based on data through the end of the first two years. Data from the third and fourth years were compared to the categorization to determine which teachers had sustained their practices and which had continued learning. Finally, characteristics of the teachers who had continued to learn where explored.

The study presents two exemplar cases of teachers who did sustain their practices. However, one of the teachers was categorized as experiencing generative change and the other was not. Ms. Sullivan exhibited generative change. As evidence of this, the researcher highlights the “detailed and complex schemes for analyzing children’s thinking” (p. 637) that Ms. Sullivan demonstrated during year four. These schemes were more complex than any offered during the professional development program. Ms. Sullivan used what she learned from her students about their mathematical thinking to continue the reformation of her understanding and conception of student learning. Because she saw knowledge as changing and connected, and allowed herself ownership of her knowledge, she was able to use her classroom experiences to continue her learning. Ms. Carroll was another successful participant in the program. She did use student thinking to inform her choices in the classroom. Unlike Ms. Sullivan, Ms. Carroll thought that the additional knowledge she needed about student thinking could only be found by taking more classes and doing more reading; “She tended to view knowledge of children’s thinking as a fixed body of knowledge that was generated by other people” (p. 676). While Ms. Carroll did believe that students construct their own knowledge in the classroom, she did not have the same beliefs about her own knowledge.

The professional development program described by Franke, et al. (2001) does share many features with the other programs previously here. These programs sought to provide experiences that would help teachers change their ideas about teaching mathematics. Some did this through the use of curriculum or teaching techniques, such as student discourse. Some programs provided teachers mathematical experiences and some approached the mathematics through pedagogy. The difference between Franke, et al. and the others is not in what the program provided, but rather in the actual research itself. The other research presented here sought to explain what teachers gained from the program or to show accomplishment of goals. Franke et al. did not state whether or not generative change was a goal of the original program. Regardless of the intent of the program, the research presented by Franke et al. makes explicit the missing emphasis on generative change.

Instead of professional development programs seeking to create teachers who have the current “best” view of mathematics, or who use teaching methods based in the most current research, professional development should have as its first goal the intent to help teachers learn how to learn. As knowledge about how people learn continues to develop, the current best practices will eventually become outdated and replaced by newer, better practices. The teachers who only learn about the practices will have to be retrained to stay current. In contrast, the teachers who learn to be agents of change will be better prepared and more able to negotiate new knowledge themselves. The teacher change cycle presented in the theoretical framework provides a process by which teachers can learn to control their own learning. Preparing teachers for generative change allows the educational system to be changed from within.

CHAPTER 3

RESEARCH METHODS

This research project is highly explorative and discovery oriented. Qualitative research methods are designed to address these exact issues (Patton, 1990). I will attempt to make sense of the changes teachers experienced, trying not to impose preexisting ideas of what those changes might be. While there may be obvious changes that the teachers experience based on the focus of the program, I want to leave the research open to discovering unanticipated changes that also occurred. Traditional methods of hypothesizing about those changes would prevent the discovery of the unexpected. Therefore, qualitative methods will be used to allow patterns of change to emerge.

The context in which teachers teach impacts teachers' practices (Guskey, 1995). This means that each teacher's classroom is a different environment, consisting of different students, different experiences, and different results to similar teaching strategies. Consequently, as the participants in a professional development program try to implement new ideas in their classrooms, they are likely to have experiences that vary from teacher to teacher, and even from class to class. Adding another layer to the complexity, each teacher enters the program having had different experiences in learning mathematics and in learning how to teach mathematics. Therefore, expecting that different teachers will experience the same professional development program differently is very realistic. Because of this, qualitative methods of research are highly desirable for this study. Patton (1990) claims:

> Qualitative methods are particularly useful for capturing differences among people and programs. Evaluating individualized outcomes, developing unique case studies of people and programs, and documenting the local diversity within national or statewide programs- these are evaluation research issues for which qualitative strategies are particularly appropriate. (p. 104)

Quantitative methods often lump teachers together, as if they were more similar than different (Janesick, 2000). The goal here is to begin to understand individual responses to the same program, so that professional development providers can better understand how to modify programs to address the needs of each participant.

Grounded Theory

This research project began with my knowledge of the two-year professional development program. During the first year of the program, I attended some of the class meetings, which were held on Thursday evenings. My participation in those class meetings consisted of videotaping the class, active participation in discussions on occasion, and providing instruction on graphing calculator use during one session. During the winter quarter of the first year, I conducted a focus group with the teachers to investigate their initial experiences with changing their teaching practices. I also provided short-term support for one participant and two quarters of support for another. This longer support included my teaching of a model lesson in the teacher's classroom. During the second year, I had periodic casual discussions with some graduate students who were providing support for the teachers and I observed the teachers' final program evaluation interviews. Due to these interactions, I had some knowledge of the stated and enacted teaching practices of some participants and some ideas about the beliefs held by these teachers. I was already forming some ideas about the kinds of changes these teachers had made in their practices. The next step of the project was to view videotapes of the teachers teaching in their own classrooms. During these viewings, I was looking for evidence of my preconceived ideas about the changes while trying to stay open to evidence of new ideas. As I watched the videotapes, new ideas did become apparent, but so did the need to find other sources of verification of those ideas. In this process, I am utilizing grounded theory methods.

Ryan and Bernard (2000) define grounded theory as "an iterative process by which the analyst becomes more and more 'grounded' in the data and develops increasingly richer concepts and models of how the phenomenon being studied really works" (p. 783). The guidelines for conducting grounded theory research are to use an inductive approach to build a theoretical framework that explains the data (Charmaz, 2000). While each step of grounded theory is not defined in a predetermined way, Charmaz stresses that each step should move the researcher closer toward development, refinement, and interrelation of concepts. Theoretical categories should be developed from the data, and must explain the data. These theoretical categories emerge from the data, and are developed and modified as more evidence is gathered.

In grounded theory, data often comes from what people do and say. In this study, the actions of the teachers, the questions the teachers ask of the students, and the answers that the teachers give to questions asked by students will be a part of the data. In addition to this, Charmaz (2000) suggests also looking “for subjects’ unstated assumptions and implicit meanings” (p. 518). Understanding tacit meanings and the underlying beliefs will aid in understanding why the teachers made the choices they did. This is consistent with what Senger (1998-1999) calls the “trying on” of ideas by teachers. As teachers learn about new methodologies, they often use discussion to try out these new ideas. Many teachers will also try these new actions in their classrooms, but often the verbalization of ideas precedes action. Through the verbalization, teachers are comparing this new idea to their held beliefs. Thus, the fact that a teacher may talk positively about trying something new in the classroom but never actually implement that new idea may be important to our understanding of that teacher, according to Charmaz.

In addition to the iterative process of analyzing data, collecting additional data may also be necessary (Charmaz, 2000; Ryan & Bernard, 2000). As the categories and foundations of the emerging theory become apparent, holes in the theory and gaps in the data may also be revealed. The work of the researcher using grounded theory is to gather more data to fill the gaps. This does not mean that the researcher is creating findings. It simply means that the researcher becomes aware that there is more to know, and must go in search of that knowing. An example of this occurred during the pilot study for this project. I thought that my prior experiences with the program would give me sufficient background to watch and analyze the videotapes. As I started watching the tapes, I was observing many possible changes, but was uncertain how, or if, these changes could even reasonably be connected to the program. I quickly realized that I needed to understand in a more concrete way the emphasis of the program to determine possible connections and included program documents as data.

Methods and Procedures

The data in this study consisted of program documents, videotapes of the teachers' classrooms taken during the two-year professional development program, participant observations, and semi-structured individual interviews. This research project takes an etic approach to classification. As defined by Pelto and Pelto (2000), etic research compares one culture to an already existing culture. My goal is to paint a picture of how the culture created in each teacher's classroom compares to the culture of mathematics classrooms developed in the professional development program, which was a reflection of the culture developed in the *Principles and Standards* (NCTM, 2000). I do not desire to make comparisons between the participants' classrooms, but rather to compare their classrooms to an "ideal" *Principles and Standards*-based classroom. Because each teacher entered the program in different stages of reform-mindedness, this research seeks to measure individual teacher's progress along the continuum. However, keep in mind that while the vision laid out in the *Principles and Standards* is encompassing and solid, it is by no means prescriptive. By that, I mean the vision is not presented as a formula, recipe, or template for what a classroom should look like, what activities a teacher should select, or even the exact content that should be taught. The *Standards* acknowledge the individuality of teachers and students. Because of this accommodation for individuality, identifying changes in the participants will be teacher specific.

Case Studies

The data I collect will be used to create case studies of the individual teachers. Case studies provide “depth, detail, and individual meaning” (Patton, 1990, p. 17) which are required to answer the research questions I have posed. Because I want to understand and explain the individual teachers’ responses to the professional development program, I will look for unique variations between participants. Case studies provide a forum for such an examination.

Participants and Setting

For this study, I used purposeful sampling (Patton, 1990). In purposeful sampling, selection of participants is based on desired attributes. In this study, the desired attributes were that teachers had completely participated in the program, and had some experience important to understanding the dynamics of reform-minded professional development. Three of the teachers were selected because they taught different grade levels in the same building and worked together on many of the projects. These teachers were also selected because of the variance in their years of experience and experience with reform-like teaching methods. Commonalities among these teachers’ efforts in reform may be partially explained by the environment in the school, or by the synergy developed by being able to share and discuss efforts on a daily basis. The commonality of the building made these three teachers of great interest to me. I selected the fourth teacher in this study because of her unique experience; she was the only teacher from her district to participate completely in the program. Her experience of having supportive people around her only once a week made her important in the study. The collection of these four teachers gives me a maximum variation sample.

The participants in this study were four middle school mathematics teachers who participated completely in the two-year professional development program. The teachers who requested a pseudonym are identified in by such. The teachers in this study are all female, as were all the teachers who participated in the program in its entirety. The years of teaching experience ranged from two to twenty years of teaching experience, as measured at the beginning of the program. The differences and similarities in these teachers were important as possible factors for explaining how the teachers responded to the program.

Data Analysis

The data for this study fell into two categories: data collected during the program and data collected two years after the program ended. The data collected during the program included data collected by me during that time period, data collected by the program director, and data collected as part of the program evaluation. The data collected after the program included interview and observation data collected by me. Appendix D provides a table identifying by participant the documents from the program that were used as data. Appendix E provides a list of the videotapes viewed for each participant. Appendix F provides a timeline of the interviews and observations I did with each participant.

Videotape Analysis

Videotapes were an important source of information about the teachers' classrooms during the two years of the program. During the professional development program, each teacher was encouraged to videotape a lesson two times each month. In actuality, the best any teacher appears to have done was videotaping once a month, with one of the participants having only five videotapes over the entire two-year period. On occasion, the teachers were asked to use problems in their classrooms, to see how the students responded. Some of the teachers chose to videotape these sessions.

Videotaping is a rich source of data. Video allows for the repeated viewing of complex scenes, which in turn allows the researcher to glean more information than one-shot observations (Roschelle, 2000). They capture tone of voice and body language along with what is actually said and done simultaneously. By doing so, videotapes suggest "the capturing of 'reality' in ways that could be said to transcend the individual researcher's relatively limited capacity to interpret (Angrosino & Mays de Perez, 2000, p. 696). However, the use of videotapes is problematic in several ways.

Videotapes are not impartial, but are in fact full of bias (Hall, 2000). One problem with using videotaping is the theoretical expectations of the person doing the videotaping. Hall talks about how the theoretical perspective of the photographer influences decisions about what to include or exclude while taping. The decision to follow the teacher around the room during group work may be the result of a belief that the teacher is the primary source of knowledge in the classroom, and thus, should be the constant focus. The choice not to use higher quality microphones may reflect a belief that the actions of the teacher and students are more important than the discussion in the classroom.

Another layer of bias is the “social construction” of photography (Harper, 2000). The videos are socially constructed because of the photographer’s relative power, or lack thereof, in the social structure of the classroom. The social norms operating in the classroom and the power structure between the teacher and the photographer contribute to decisions about what is preserved on tape. Since a variety of people served as photographers during the program, the videotapes came to me already laden with a variety of biases. The decision to exclude conversations or actions on tape has limited my access to the teachers’ attempts at change and shapes the picture with which I am presented. At times, these excluded elements may have been key indicators of the change a teacher was experiencing. This inherent bias makes the interviews with the teachers vitally important.

Additionally, several authors point toward the fact that videotapes cannot capture the complete experience. While much is captured on tape, the “lived experience” (Angrosino & Mays de Perez, 2000) is still absent. This “lived experience” comes from interactions and shared experiences over time. The teachers and students are working in what Roschelle (2000) calls a long-term context. While the video captures what was done today, it does not share the past histories that led to the development of the current classroom culture. Videotaping every day, starting as the teacher is setting up the classroom at the beginning of the year, might provide such information. However, such mass amounts of data become unmanageable. Clearly, videotaping contains enough faults that other sources of data become necessary.

Document Analysis

In addition to the videotapes, I examined documents collected during the program and will use some documents about the program, such as the syllabus. To understand where the program directors had placed emphasis, I will examine the syllabi for each quarter of the program. In long-term professional development programs, teachers make advancements in areas identified as a focus for the program (Jones, et al., 2000; Swafford, 1999). The syllabi serve as a means to identify specific goals for the program. As well as stated goals, I will use patterns in the readings and the topics for each class as indicators of the program's focus.

One additional document that will provide information is the goal statements of each teacher. At the beginning of the program, the teachers were asked to state their goals in writing. Periodically, throughout the program, the teachers would reevaluate their goals, and make modifications to or completely change the goals. Since these goals were presumably areas of interest for the teachers, these goals may provide some insight into changes the teachers were attempting to make. Statements of goals that reflect changes seen on the videotapes will serve as additional evidence of that change. Goal statements reflecting practices that should be evident in the videotapes but are not could serve as important non-examples in the data. Therefore, these goal statements are additional data that I need to access and analyze.

The teachers also kept journals during the program, in which they responded to prompts written by the program directors. Although the teachers were responding to a prompt and not writing about self-identified concerns, these journals may still be useful for providing insight into the kinds of changes the teachers attempted. The journals will serve as an additional source of data.

Interviews

Individual semi-structured interviews were conducted with the participating teachers. These interviews were held after I viewed the videotapes and analyzed the program documents, but before I observed the teachers' current classrooms. I conducted a second set of interviews after doing the classroom observations. "The opportunity to learn about what you cannot see and to explore alternative explanations of what you do see is the special strength of interviewing in qualitative inquiry" (Glesne, 1999, p. 69).

I have chosen a semi-structured interview format because of the focus on individual reactions to change. Fontana and Frey (2000) categorize interviews as structured and unstructured. In a structured interview, all the participants are asked the same questions with the same wording, in the same order. Unstructured interviews, in contrast, are described as open-ended attempts to "understand the complex behavior of members of society without imposing any a priori categorization that may limit the field of inquiry" (Fontana & Frey, 2000, p. 653). Patton (1990) refers to the same configuration as the general interview. He suggests the use of an outline of issues that are to be discussed with each participant. The order of the outline is flexible, but each topic should be addressed. These formats address the needs of this study by their flexibility.

Based on the videotape and document analysis, questions will be individualized. Although the individualized questions will focus on understanding decisions the teachers made about lesson content, students to call on, and room and seating arrangements, the questions will address specific instances from an individual's tapes and other data sources. If the need arises, I will be prepared for teachers to review videotapes during our interview session.

The way a question is worded is important to the kind of response elicited (Glesne, 1999). By using a semi-structured interview setting, I allowed the possibility for the discussion to go in directions I had not anticipated. For the interviews, I created a set of common questions, but I did ask some impromptu questions to clarify comments or follow up on thoughts. For the impromptu questions, phrasing the questions so that they did not appear to be judgmental or harsh was difficult at times and did require a conscious effort on my part. Narrowing the topic of interest is a large step of the interviewing process, but asking questions that get at that target is truly an art.

Collecting data through interviews was important because of the limitations of videotaping. The semi-structured interview format will allow me to ask the teachers questions about changes they claim occurred that were not apparent in the videos, and to ask more details about the changes I thought I saw on the videotapes. I also used other data sources to corroborate changes claimed by the teachers that were not apparent in the videos. The semi-structured interviews also allowed me to pursue the teachers' explanations of examples of changes I thought I had seen in the videos but that the teachers did not classify as changes. A sample interview protocol from the preobservation interview is included as Appendix B and the post-observation protocol is included as Appendix C.

Observations

"What people say is often very different from what people do … thus a full sociological analysis cannot be restricted to interview data. It must also consider the material traces" (Hodder, 2000, p. 703). The purpose of collecting observational data is to understand and describe the setting, the people in the setting, and the activities that took place. These observations served to triangulate the information I had about the changes in teaching practices.

The criterion for judging recorded observations is "whether that observation permits the reader to enter into and understand the situation described" (Patton, 1990, p. 202). Because of the complexity of the classroom, observing and recording everything was impossible. I decided not to videotape the observations because some of the teachers were reluctant to videotape themselves. Not wanting to increase their discomfort, I only audio taped the observations. Even with this technology, capturing everything was impossible, as well as unnecessary. I focused my observations on the kinds of changes the teachers had identified in their journal responses and in the pre-observation interviews. In focused observations, some things can reasonably be ignored because of their non-relevance to the research at hand. However, one must be careful not to ignore too much, because subtle factors can be impacting the decisions made by the teacher. For example, imagine a teacher planning to do a group problem solving activity on a particular day. As the end of the class nears, with no solutions yet obtained, the teacher makes a decision to wrap up the problem by showing the students how to do the problem. This action by the teacher could have occurred for many different reasons, ranging from a belief that the teacher is the authority and needed to show the answer, to knowledge on the part of the teacher that for the next several days many students will be out of class for various reasons. Other clues during the class might have been available to help the observer understand the teacher's motivation for giving the solution and should be attended to in the analysis of the class. Along with attending to relevant aspects of the observation, these ambiguous situations highlight the need for interviews to support observations (Angrosino & Mays de Perez, 2000).

Researchers need to remain flexible in their point of view (Glesne, 1999). The act of observing means that the researcher has chosen to look at some things and not at others, thus selecting a point of view (Harper, 2000). While observing, the researcher's job is not judgmental or evaluative. The purpose is to gather enough data to understand the classroom culture and the motivations of the teacher. I anticipated that maintaining an open viewpoint would be difficult for me, given my experiences as a teacher and supervisor and the beliefs that I have developed from those experiences. I was in the classrooms to compare the changes the teachers made against the vision of the *Principles and Standards* (NCTM, 2000). I wanted to gather the data without being judgmental, but I found this position difficult to maintain.

One goal of this research project was to understand how a specific professional development program impacted the participants' classroom practices. There are obvious ways this happened; some of those ways were apparent to the program providers by the end of the program. However, the observational fieldwork provided an opportunity to become aware of things that were not so quickly obvious. There were aspects of the change that did not appear until the teachers began operating outside the structure of the program. There were beliefs held by the teacher that were not explicit during the program, which did become more explicit as the teachers tried to implement changes.

Observations provide a means for detecting the often ignored (Patton, 1990). Noticing what has previously been ignored can be a difficult task. Glesne (1999) states:

> To make the familiar strange is often more difficult because you must continually question your own assumptions and perceptions, asking yourself: Why is it this way and not different? Overcome your disposition to settle into a way of seeing and understanding that gives you the comfort of closure at the price of shutting down thought. (p. 46)

This quote stresses the need for some kind of checkpoint to remind me to shed preconceived notions about what should be happening. Different researchers of equal ability to do research may very well produce observations that are vastly different because of their different experiences and points of view (Angrosino & Mays de Perez, 2000). This should not be seen as a weakness in observations, but rather serves as a reminder to make readers aware of the biases with which researchers operate. As a researcher, I must stay actively aware of how my past experiences are influencing what I see and how I interpret what I see.

Besides differing in the scope of what is observed, observations can also differ in the amount of participation by the researcher in the environment being observed and the duration of the observations. The continuum of researcher participation runs from separation to full participation (Glesne, 1999; Patton, 1990). While I have taken an active role in some of the classrooms in the past by providing support, my role when observing for this project was closer to separation. The data I collected did not require my active participation in the classes and might have been distorted by my participation. My role in those classrooms was to watch what was happening, and not to directly influence the actions. Patton warns that my very presence did have some impact on the classroom, but I hoped to minimize that influence by restricting my interactions.

Observations can also vary in length. In determining how long observations should last and the time period over which they should continue, Glesne (1999) offers a simple suggestion to "stay long enough to get full description and a deep understanding" (p. 45). Currently, all four of the teachers are still teaching in the buildings and at the grade level that they were teaching in during the program. All four teachers are still in the same classrooms as when they were videotaping for the program. Because the observations were similar to the videotapes in the aforementioned ways, I felt some sense of familiarity when I entered the classrooms. Generally, the observations lasted from three to seven days, with some classes requiring more observations than others.

Validity and Reliability or Trustworthiness

For this study, I used three methods of establishing trustworthiness, as recommended by Lincoln and Guba (1985): triangulation of methods, prolonged engagement, and member checks. I triangulated the data by using multiple data sources. I examined findings from any one source in light of the other two. Prolonged engagement arose from my involvement during the program, the videotapes which were taken over a two-year time period, and the extended classroom observations which I conducted. Member checks occurred as I discussed what I had observed in the videotapes with the teachers to clarify the motivation behind the observed change. The teachers were also able to use that time to make me aware of changes not evident in the video and document analysis.

Limitations

One major limit of the study is summarized by Patton (1990), “the data simply describe what occurred” (p. 31). This statement serves as a reminder of the naïve position researchers can take when using videotapes, documents, and observations. The videotapes in this study are only brief glimpses into the teachers’ practices and are full of bias on the part of the photographer. While the tapes provide valuable information, that information must be confirmed using other sources. As Harper (2000) says, “it is easy to see that empirical evidence is both constructed and real” (p. 31). The videotapes provide a picture that has been drawn with many different hands and is a limited view of the classroom. The observations can also been seen as constructed by what the observer chooses to see or ignore. The observations will be completed by a person with many years of teaching experience and two years of experience supervising student teachers. This person has a very different view of the classroom than a researcher with no teaching experience, which is even different that a researcher with five years of teaching experience. The data collected was translated and analyzed through one particular lens. Staying aware of that lens was important to me, the researcher, during data analysis.

Thinking that videotaping or observing can be accomplished with a clearly objective lens is naïve and would only serve to hide the bias.

The Pilot Study

A pilot study using videotape analysis, document analysis, and individual interviews was conducted in the Spring of 2003. For the pilot study, three teachers were selected using the criteria of complete participation in the program and varied years of experience. Three teachers who taught in the same building were selected. This group of three teachers were from a different building than the three teaches in the research study. During the program, I provided support for two of the teachers who participated in the pilot study, giving me some familiarity with their classrooms and teaching practices. Because of my familiarity with their classrooms, the pilot study began with the videotape analysis. During the videotape analysis, I quickly realized that even with my prior knowledge of their classrooms, I needed additional information to understand the teachers and the changes they made. This led to the inclusion of documents from the program as part of the data for the research study. From the document and videotape analysis done for the pilot study, interview questions were constructed. These interview questions were then critiqued and improved with the assistance of a group of graduate students and faculty professors participating in a research group. The questions were then piloted with the first teacher. Following this interview, additional changes to the interview questions were made and then piloted with the two remaining teachers. The final set of questions were modified slightly to individualize the questions for the participants of the research study.

The pilot study had a great impact on the procedures of the resulting study. While several ideas emerged from the videos, the absence of other ideas was surprising. For example, I expected to see a more gradual change over time. However, for two of the teachers, all the videos seemed to be similar until the final video. I realized that I had made the assumption that the videotaped lessons would represent the "best" lessons for each teacher, which does not seem to be the case. Several of the research study teachers commented that they videotaped based on convenience rather than on a desire to video their best lessons. This may have been a factor of the camera's availability or the support person's schedule. The videotape viewing for the pilot study brought forth many examples that I interpreted as evidence of change, but that the teachers did not view as changes. This made clear the need for me to discuss my thinking about the videotapes with the teachers participating in the research study.

CHAPTER 4

THE SETTINGS AND CONTEXT

Understanding the changes and the cycle of change through which the teachers in this study underwent requires a conceptualization of the professional development program in which the teachers participated. Understanding the lens with which I interpreted the data requires a better understanding of me. Therefore, the first part of this chapter will provide a description of the professional development program and its components. I will also elaborate on my experiences and how I came to be involved with the program. Finally, a section of this chapter will be used to create a word picture of the four teachers' classrooms and school environments.

The Professional Development Program

My knowledge about the program was gathered from 4 different sources. I have used three different written sources; the original program proposal (Pape, 2000), the course syllabi from the program and an article published by the director of the program and another instructor who had an integral role during the first year (see Pape & Costner, 2002). I also attended some of the courses during the first year and provided support for the teachers during the first year, this being my third source of information about the program. My fourth source of information comes from the informal conversations I had with the director, instructors, and graduate students who provided support for the teachers during the second year of the program.

The professional development program in which these teachers participated was titled *The Teacher-Researchers: Making a Difference in Mathematics Teaching and Learning Through Inquiry* program and was conceptualized and implemented by Dr. Stephen Pape, the director of the program (Pape, 2000). This program was a two-year program, in which the teachers took one class each quarter. The goal of this program was to improve student learning and academic achievement by involving the teacher participants in the study of pedagogy, learning theories, and mathematical content. The teachers videotaped their classrooms and reflected on their classroom practice in light of their new knowledge about pedagogy, student learning, and their own mathematical knowledge. With the help of a university research team, the teachers developed action research questions, conducted an action research project. Throughout the two-year program, the university support team provided the teachers with assistance in the teachers' efforts to change their teaching practices.

The courses started in the summer of 2000 and ran through the spring of 2002. Along with the course work, each teacher worked with a university representative who provided support to the teacher in the teacher's classroom. Support was provided by the director, the other instructor, and doctoral students who had experience teaching in a K-12 classroom. Because the teachers were implementing new ideas in their classroom, the support personnel were there to assist the teachers in many ways. Some examples of the support provided include teaching model lessons in the teachers' classrooms, gathering information about specific ideas a teacher wanted to try, videotaping lessons taught by the teachers, collecting data within the teachers' classrooms, and generally providing moral support for the teachers' efforts at reform.

The program was designed to have teams of teachers from a school district working together to strengthen mathematics education in their district. While several groups of teachers participated as a building teams or district teams, there were other groups that shared only a common district. One teacher participated as the sole member of her school district, although other teachers from her building did attend some of the classes during the first summer. This program was designed to help teachers reflect on current knowledge about mathematics education and to reflect on their own teaching practices and classrooms. The ultimate goal of the program was to assist the teachers in moving their practices closer to the vision set forth in the NCTM *Principles and Standards* (2000) (Pape & Costner, 2002). The program provided a systematic approach to accomplishing the goal. The early courses focused on the exploration of existing state and national standards, along with research about mathematics learning and teaching. Following this exploration, the participants studied specific mathematical content, with instructors who purposely used methods consistent with the research and standards the participants had been studying. Finally, the participants implemented the knowledge they had gained by selecting individual goals for action research projects targeted at changing a specific part of their teaching practices. Many of the teachers used the courses from this two year program as a springboard to their masters degree.

Now that the reader has the overall picture of the program, I will provide details about each quarter of the program. The first quarter of the program occurred during the summer of 2000 with a course on mathematics education. This course focused specifically on an exploration of the vision of mathematics classroom presented in the *Principles and Standards* (NCTM, 2000). Following this, the groups began to examine the Ohio Mathematics Content Standards (Ohio Department of Education, 2000). Both documents were examined by the teachers in cross-grade level groups. This exploration was done in cross-grade level groups and in grade level groups. The goal of the quarter was to familiarize the teachers with these documents and the visions represented therein, and to begin discussions about how the teachers' classrooms reflected or differed from these visions. The remainder of the course was spent with the teachers developing instructional units in cross-grade level groups. These units were intended for implementation in the teachers' classrooms in the autumn. Each week of the class, the participants also read articles addressing issues of understanding and implementing the standards. This first course exposed the teachers to the national and state standards and opened the doors for future study of the research base about learning mathematics on which those standards were developed.

The second course in the program convened after the teachers had experienced almost a month of a new school year. Having been exposed to the standards, the participants spent this second quarter studying assorted issues connected to standards-based teaching. By reading articles addressing different issues in mathematics education related to reform teaching, the teachers were exposed to the research literature and to the literature about the applications of the research. Some of the topics during this quarter were discourse in the classroom, teaching for conceptual understanding, technology in mathematics classrooms, problem solving, the use of multiple representations in mathematics teaching, and case studies of teacher change (Autumn 2000 syllabus). During the autumn 2000 quarter, the teachers began the process of videotape reflection, which continued through the winter and spring classes and into the second year. The teachers videotaped their classes and presented sections of their videos to the whole group. These videotapes were used as starting points for discussions about the trials and successes of trying new ideas in the classroom. Also during the autumn 2000 quarter, the instructors began the process of having the participants reflect in writing on their practice. Some journal responses were written during class meetings and others were assigned to be completed outside of class. During this quarter, the individual participants began the process of exploring specific ideas for change in the classroom. By reading articles outside the assigned reading, the participants began to familiarize themselves with the literature surrounding a specific topic of interest.

Having spent two quarters examining issues in mathematics teaching, the third course immersed the teachers in a mathematical learning experience. As suggested in the NCTM *Principles and Standards* (2000), teachers need to be exposed to authentic experiences of learning mathematics that model the ideas in the *Principles and Standards.* With this in mind, the instructors, along with a mathematics professor, spent a quarter teaching topics related to the mathematics taught in the middle grades: proportional reasoning, fractions, linear relationships, functions (Winter 2001 syllabus).

Because mathematics teachers often view their college mathematics professors as authorities to be respected, having a college mathematics professor serve as one of the instructors reinforced the message that the teaching practices being used were valued by an expert in the field. By learning mathematics from a person respected for his content knowledge, these teachers had good mathematics teaching modeled for them.

The topics for the mathematics courses were selected because of their complexity and importance in future mathematical content, and because of the room for improvement in how these topics are often developed for middle grades students. The participating instructors sought to include activities, standards-based teaching practices, and technology to model for the teachers how these topics could be presented to students. Also, a conscious effort was made to make the pedagogy of the lesson explicit and the participants were encouraged to discuss their reactions to the teaching methods. The teachers were also asked to develop, teach in their own classrooms, videotape, and formally reflect on a lesson based on one of the mathematical topics discussed during the quarter. I would call this quarter an application quarter. The teachers had discussed topics, started to look at issues, and, through their research, had begun to focus in on specific areas of interest. During this content course, the teachers were experiencing a standards-based classroom as a student. As the participants began to focus their efforts on a specific change they might make in their own classroom, they had been provided with opportunities to experience that kind of learning on many different levels.

The fourth course, during spring 2001, started the teachers on the process of formally researching some change they wanted to make in their classrooms. The topics for this quarter were: action research, critique of videotaped instruction, motivation, teacher expectations, self-regulated learning, mathematical instructional practices, and classroom questioning techniques. Except for the focus on action research, the focus on this quarter was determined by the participants. By this point, the participants had narrowed their areas of interest about a formal change they would make in their classrooms. By formal change, I mean one they would research through an action research project. The topics listed for study during this quarter reflect the areas that the teachers had preliminarily selected for their action research project. This quarter was structured more like the Autumn 2000 course, with readings, reflections, and discussions of videotapes. During the quarter, the teachers were also encouraged to share exemplary lessons with each other by providing lesson plans and activity sheets to others in the class. The students who were going on to pursue their masters degrees had an additional assignment of beginning a formal literature review connected to their action research topics.

Along with the course work, each participant had a support person helping the teacher. Often, the support person assisted the teacher by setting up and running the video equipment for the required taping of lessons. Some support people did some team teaching with the teachers, providing an extra pair of hands in the room as the teachers experimented with new activities or technologies. One support person was able to work almost as a mentor to her teachers, observing while videotaping and then reflecting with the teachers on the strengths and possible improvements of a videotaped lesson. Some teachers had their support person assist with copying and keeping track of student work being used in the teacher's research. Other support personnel used their research skills to help the teachers find appropriately scholarly articles for use in the literature review. Although time constraints and other university obligations on the part of the support personnel sometimes limited the possibilities, the participants were encouraged to work with their support person in ways that addressed the participants' individual needs and efforts.

The focus of the second year of the program was mostly on the participants' action research projects. During the summer, the teachers continued to review videotapes made in their classrooms the previous school year and continued discussions about topics such as student motivation, self-regulated learning, and more exploration with mathematically rich problems. However, half of the credit for the summer 2001 course was assigned to the completion of a research proposal for the action research project the teachers would undertake in the autumn. Time was spent during the course helping the teachers conceptualize and plan their action research projects. For at least two different topics, discourse and questioning, groups of teachers decided to explore the same change in their classroom. These groups worked with the project director or a knowledgeable resource person to detail their projects and discuss their ideas. Some participants worked on topics on which no other participants were working. These participants worked on a more individual nature with the program director and support personnel to map out their projects.

At the start of the 2001-2002 school year, the teachers began implementing their action research project. When they began meeting for the professional development program that September, the progress of their projects was a major component of the course. The groups who were working on similar topics shared their progress with each other, while those working on individual ideas shared their progress with the professor or with each other. However, the autumn course was designed to continue the emphasis on standards-based teaching. The quarter included discussions of readings and analysis of videotapes from the teachers' classrooms. Although many of the videotapes were focused on the same aspects as the action research projects, the readings and discussions were structured to continue further explorations outside the action research topics. These additional topics were designed to build on the progress the teachers had made so far, and to push their thinking and development further. Included in the quarter were discussions about building self-regulated learning in the classroom and developing open ended problems for use in the classroom.

The winter 2002 course focused on mathematical content. As with the winter 2001 course, a mathematics professor co-taught the class with the program director. The emphasis for this quarter was on algebraic reasoning: patterning, the role and development of variables, and the use of manipulatives in algebraic reasoning. As with the previous winter, the participants studied the content as students, and through discussions and assignments, the pedagogy of the course was made evident. Although the content was selected because of its place in middle school mathematics, the instructors worked to make the learning an authentic experience for the participants. The participants did discuss how they thought their students would engage with aspects of the lessons, but the participants were not asked to pretend they were middle school students. The content, discussions, and explorations were designed to push the participants' knowledge of the topics beyond where their students might need to go, but in a way to further strengthen and deepen their mathematical knowledge. This quarter was different from the previous winter because other teachers from area school districts also participated in this course. The class size was much bigger than during the previous winter.

The final quarter of the course was the spring quarter of 2002. This quarter might best be titled "Data Analysis." Even though their school year had not yet ended, the teachers concluded their data collection and began the process of analyzing their data. The analysis was done in groups with their support person. For example, all of the teachers looking at discourse in their classroom worked together with a single support person for assistance. The participants who had more individualized projects joined teams whose topics were similar, or formed new teams along common themes. With the help of the instructors and support personnel, the teachers completed their analysis and wrote a final report of their findings. Some of these final reports eventually morphed into journal articles written by an individual as a support person or by a group with a support person. Although the action research process was beneficial for the participants, I recall the director stating after the program's completion that this process became more formal than was necessary for informing classroom practice. Many of the projects conformed to strict quantitative analysis methods, as did the analysis. A more informal approach to the analysis process might have increased some participants' interest in the research process.

The official end of the program occurred with a final evaluation focus group held during the summer of 2002. The teachers responded to questions in writing and then were asked to follow up on those comments in a focus group session. However, several of the teachers, three from this study, went on to complete courses towards their masters degree over the next few quarters.

In the description of the program, an important piece of information is missing. Necessary in understanding the participants' interaction with the program elements are several relational factors developed during the program that set the tone for the program. First, the group of teachers who completed the program highly respected the director of the program. In the final evaluation, several of the teachers specifically named the director of the program as one of the strongest factors in the success of the program. The participants in this study often commented on how well the director understood the classroom and the changing needs in the classroom. Not only did the participants respect the director, the connection between the director and the participants developed into a friendship. Lorraine, one of the participants in this study, commented during an informal conversation about the quarter in which teachers from outside the program joined the course. Lorraine said the program participants resented having to share the program director that quarter. Although this was said in a joking manner, the comment reflects the attachment that had developed between the director and the participants.

The second equally important relational factor was the peer support and relationships developed among the participants themselves. Most of the teachers had colleagues from their building participating in the program. The three teachers in my study who were all from the same building commented on the support they drew from each other. For example, Lorraine, who had her second baby at the end of the spring 2001 quarter, reported that continuing into the summer was only possible because the teachers knew her and understood her situation with the baby (October 27, 2003, Pre-observation interview). Nicole mentioned sharing ideas with another teacher from her building who taught the same grade level as Nicole. This other teacher was in the program, but did not participate in this study. Being able to remind each other about assignments that were due and being able to discuss things within the context of their school was very valuable to all three teachers. All three of them referred to the other teachers in their building as friends, and commented on missing the weekly interactions with those teachers.

Clearly, the program design follows the practices of reform-minded professional development though the long-term engagement, support in the teachers' classrooms, consideration of mathematical content and content specific pedagogy, and the flexible consideration of teachers' individual needs. Additionally, the program directors and others helping to run the program worked together, leading to the development of a trusting environment in which the teachers were able to operate with the director and with each other. The participants labeled the program a resounding success and many of the participants would have willingly signed up for another two years.

The Researcher's Background

Having described the program, I will now try to help the reader understand the lens through which I operated. My experiences have influenced who I am and necessarily influence how I interpret the events around me. Therefore, knowing something about my past experiences will help the reader better understand how I have interacted with the data in this study.

My experiences influencing who I am as a teacher began in my bachelors degree years. I studied to be a teacher as an undergraduate in a four-year program. Although I was never the strongest mathematics student in my classes, I did take higher level courses and enjoyed mathematics. I remember thinking that the instruction in my college level mathematics classes was lacking in some way at times, but I was never able to quantify clearly what was missing. In my education courses, however, I was somewhat arrogant and viewed many of those classes as being useless to me as a new teacher. I remember thinking that I already understood the mathematics I needed to know to teach seventh through twelfth grade mathematics classes, and that learning to write lesson plans in a style that classroom teachers did not use was not an experience I needed. Therefore, I left my undergraduate life not wanting to take any more education courses.

During my first year of teaching, I taught three sections of geometry. A much more experienced teacher, Mr. Maker, also taught several sections of the same course. Mr. Maker kindly worked with me, sharing his experience and ideas. I came to rely on him for input on how to approach lessons and as a gauge for how long topics should take to cover. During the spring quarter of that year, Mr. Maker had a student teacher with whom I developed a lasting friendship. The collaborative nature of my work with Mr. Maker continued along with the student teacher. Therefore, during my first year of teaching, I developed an expectation that mathematics teachers could and should collaborate.

Even as I started my first year of teaching, I had plans to pursue my masters' degree quickly. Having no desire to take more education classes, I enthusiastically entered a Masters of Arts for teachers program that was housed within a university mathematics department. Over the next three summers, I pursued my degree, and taught high school mathematics classes during the school year. However, during the second and third summer of my masters' degree program, I became increasingly critical of the mathematics instruction I was receiving. During my final summer, Dr. Bert Waits visited one of our classes as a guest speaker. During this visit, we were introduced to the prototype of the graphing calculator, but more importantly, we received a copy of a computer software program called "Master Grapher." This program functioned much like the graphing features of the very early graphing calculators. During this presentation, we went through a discovery lesson on the relationship between the equation and the graph of a quadratic equation written in vertex form. Having struggled with my own knowledge the previous school year when teaching this concept to an Algebra II class, I experienced an "ah ha" moment. Needless to say, I used the program and the discovery lesson the next year in my class.

That one single session with Dr. Waits in my masters degree work, and the success I had implementing that same lesson in my own classroom the next year, made me hungry for more professional development. I was now ready for the information my undergraduate education professors had been trying to share with me. The climate in the district where I taught was not conducive to pursuing professional development, so I accepted a position in a growing district that had recently hired a mathematics specialist. My first year in the new district also marked the first year of that district's emphasis on their mathematics program. Many opportunities were made available to mathematics teachers in the district to learn about using manipulatives to build conceptual understanding. Through these professional development programs, I learned about standards-based teaching and began using some of those ideas in my classroom.

I was still unconsciously struggling with beliefs about mathematics and learning that were in opposition to standards-based ideas, but my excursions with new teaching methods were forcing me to become aware of some of those beliefs. For example, in my last year in that district, I was teaching a class called Consumer Math. The students in this class were mostly high school freshmen. Originally, these students were slotted to take Pre-Algebra the following year. However, changes in state and district policies resulted in the decision being made that this group of students were go into an Algebra I class the next year, even though they had not had an official Pre-Algebra course. Being confronted with this decision with one quarter left in the year, I had to decide what concepts these students most needed to survive the next year, and make decisions about the best way to deliver that material. I struggled with a long list of mathematical procedures on the one hand, while, on the other hand, wanting these students to have a strong conceptual understanding to carry them into Algebra. I made the decision that using hands-on methods and some discovery activities to develop deep conceptual understanding of a few ideas would be the most beneficial to these students. Making this decision was a turning point in my views and beliefs about what teaching mathematics means to me.

Following this defining moment in my beliefs, I had the opportunity to move to a growing independent school to develop the high school mathematics curriculum. Having had the opportunity to confront my beliefs and having changed some of my beliefs about mathematics and mathematics teaching, I was now in a position to implement those ideas on a larger scale than just in one class. During the first two years at the school, I was the only high school mathematics teacher, which made having a standards-based high school curriculum easy. However, as the school continued to grow, additional faculty were needed to cover all the classes. As we hired new people, I was charged with sharing the school's philosophy of teaching with those teachers and with helping them confront their beliefs and practices that might be contradictory to the philosophy I had developed. Although we tried to hire people whose views were aligned with the school's current practices, the actual implementation of those ideas often revealed deeply held beliefs that prevented the teachers from buying into standards-based teaching completely. I began to develop an interest in the differences between teachers who seemed to naturally gravitate to standards-based teaching, teachers who needed mastery experiences to convince them that standards-based teaching methods had value, and teachers who were completely resistant to what I considered good teaching practices. As I worked with other high school and middle school mathematics teachers, I began to understand that some teachers viewed mathematics as a collection of procedures, and that some teachers held a belief that only certain students were able to learn mathematics. I also had to confront in myself some tendencies towards those same beliefs.

Through discussions with several levels of administration at the school, several things happened. First, the district undertook efforts to evaluate the teaching of mathematics across grade levels and to consider serious efforts to ensure that the written curriculum, texts, and other documents convey to teachers that teaching for conceptual understanding through the use of multiple methods was an expectation in this district. Appropriate grade-level and course-level training was held to help teachers understand what those expectations would look like in the classroom. Also, my part in these efforts caused the upper administration to encourage me to pursue a doctoral degree, to increase my knowledge and legitimacy in directing the district's efforts. Thus, my official pursuit of academic knowledge regarding the process of changing teaching practices began.

My doctoral studies provided me with the language to talk about the things I had observed in my efforts to develop a standards-based high school curriculum, and exposed me to the efforts of others who had pursued the same goals. Having taken a course with the director of the *Teacher-Researchers* professional development program, the opportunity became available to work with teachers who were trying to change their teaching practices. Because these teachers were working in large districts, urban and suburban, I was able to compare their efforts to the efforts of the teachers in the smaller, independent school where I was working.

All of the previously described experiences contributed to the development of the person I am. That person is someone who has changed her own teaching practices, and realizes that there is still much room for growth. Although I have changed my beliefs about what mathematics is and what mathematics teaching should look like, I still find myself confronting discrepancies between my practices and my idealized vision of what I want my practices to be. In my work supervising student teachers, I am constantly challenged to convert my vision into actual ideas that will work in my student teachers' classrooms. I have learned that changing one's own practices is a very different experience from helping others change their own practices. However, having made those changes myself, I am less tolerant of teachers who consistently resist change. I find myself struggling with the excuses teachers provide as reasons for not implementing changes. I often find myself making judgments about teachers' progress, a practice which may interfere with data analysis at times. Throughout data analysis, I tried to be consciously aware of this tendency and tried to refrain from viewing the data with a judgmental eye. However, knowing that this is a tendency of mine, the reader will want to read critically.

Participants' Settings

In the next chapter, I will present the data that demonstrates the kinds of changes the teachers made during and after the professional development program. I will also explore the reasons the participants in this study made changes, sustained changes, and reasons for lack of changes. To adequately understand that information, the reader must have some idea of who these teachers are as classroom teachers and the settings in which they teach. The following section will provide a description of the schools, the teachers' classrooms, and how the teachers function within those classrooms. I realize that a teacher's life outside the classroom contributes to the persona of the teacher in the classroom. However, information about the teachers' "real" lives was not available from before or during the program. I made the decision not to ask the teachers questions specific to their lives outside of the classroom. At times, teachers offered information about their personal lives, and such data may be included in this study. However, I did not solicit personal information about the teachers' lives outside of school.

Lorraine's, Nancy's, and Nicole's District and Building

Lorraine, Nancy, and Nicole all teach in the same middle school building a large, urban school district. The building is situated in a neighborhood with smaller and medium-sized, well kept houses, on lots that are larger than those in the typical new housing developments. Because the houses are older, the trees and landscaping are well developed. The building itself is the same floor plan as another middle school in the district which I visited in my role as a student teacher supervisor. The two buildings had very different atmospheres. The building in which Lorraine, Nancy, and Nicole teach feels like a suburban middle school. According to Nancy, no great changes have occurred concerning demographics in the building over the last four years. For the 2001-2002 school year, the school had 550 students: 54% White, non-Hispanic; 36% Black, Non-Hispanic; less than 1% Asian; less than 1% Hispanic; and 36% eligible for free lunch (National Center for Education Statistics, n.d.). According to the Ohio Department of Education (ODE) 2002-2003 school report card, 12.2% of the students have limited English proficiency (ODE, n.d.). This building is a middle school with grades six through eight.

Lorraine, Nancy, and Nicole have all been teaching their current courses for at least the last four years and have been in their current classrooms for that time also. These teachers do not share a classroom with other teachers. This allows the teacher access to their classrooms during their two planning periods. Nancy teaches sixth grade mathematics and sixth grade Health. Nicole teaches seventh grade Pre-Algebra and seventh grade Health. Nicole did have a few sixth grade students in her Pre-Algebra classes. Lorraine teaches eighth grade Algebra and eighth grade Algebra-Readiness. Lorraine is the sole mathematics teacher in the eighth grade, which means that she sees all the eighth grade students. Nancy and Nicole both share the mathematics load for their grade levels with another teacher, so both Nancy and Nicole see only half of the students in their grade level.

The school day is segmented into eight 38-minute periods, with an additional segment of time in the middle of the day during which each grade level has lunch, recess, and Academic Prep (AP) time. During their AP time, the teachers have a duty such as detention or in-school suspension supervision. Out of the other eight periods, each teacher teaches six of the eight periods, and has two periods for planning time. Nancy and Nicole both have their students in two-period blocks every day. For example, Nancy had a group of students who came to her room at the beginning of the first period and did not leave her room until the end of the second period. She had another group of students who were with her during the third and fifth periods every day. Nancy had a planning time during the fourth period, so these students met with her during third period, would leave to go to another class during fourth period, and return to Nancy during fifth period. Because Nancy does not have to share a classroom, the students who saw Nancy in non-consecutive periods often left their mathematics materials on their desk, ready and waiting for their return. Nicole's schedule was very similar to Nancy's, with the only difference being the timing of her planning periods. Both Nancy and Nicole had been teaching under the same structure for at least the last four years, with changes only in the timing of their planning period or the duty during AP time. Therefore, Nancy and Nicole had the same kind of schedule during the two years of the professional development program, and during the two years after the end of the program.

Lorraine’s schedule was structured differently. During the professional development program, and during the year prior to my observations, she had a class of students every day for a 38-minute period. During the year of my observations, the eighth grade daily structure had been modified. The schedule had been adjusted to blocks of time, similar to the sixth and seventh grades. However, instead of seeing her students every day for two periods, Lorraine only saw her students two days a week for two periods, and one day a week for only a single period. For example, on Mondays, Lorraine saw every class for 38 minutes. On Tuesday and Thursday of that week, she would see her fourth period class during the fourth and fifth period time slots. While she had the 4th period class, the fifth period class was spending those two periods with their science teachers. On Wednesday and Friday of that week, Lorraine would see the fifth period class during the fourth and fifth periods, while the fourth period group was with the science teacher those two periods. Because of her planning periods, Lorraine had some groups that were in her room for consecutive periods and some that were in her room for non-consecutive periods. For example, her first period group would see her on their two days during the first period, leave her room to go to an English class during the second period, and return to Lorraine’s room for third period. Again, because Lorraine did not have to share her classroom with another teacher, the students in the non-consecutive periods often left their mathematics materials out on their desks, waiting for their return.

Nicole's Classroom

Nancy, Nicole, and Lorraine have created very different classroom environments. Nicole's classroom looks like a typical classroom, except she has a vast amount of storage space in the back of the room. At the front of the room, Nicole has chalkboards that go across the front wall. She also has an overhead projector on a table at the front. On this table, Nicole usually has placed the materials she needs for the period, such as her grade book, the textbook, and any handouts and manipulatives the students will use. Nicole also has three computers in her room, along the side wall. The desks in Nicole's room are arranged in rows running from the front to the back of the room. Although she occasionally had students work in groups, usually the only groups who move their desks into groups are the groups in the rows closest to the computers. There is more room on this side of the room. The other students in the room usually turn their bodies instead of rearranging their desks.

Nicole has and established classroom routine. As students enter the classroom, Nicole has a warm-up problem on the overhead. Occasionally, the problem is written on the chalkboard. The students immediately begin working on the problem in silence. While they are working, Nicole circulates about the room checking their homework, looking at students' work on the warm-up problem, or dealing with issues of absences and make-up work. After sufficient time, Nicole frequently asks for student explanations. Following the student's explanation, Nicole typically clarifies some aspect of the problem. These warm-up problems may be connected to the district-wide test for the course, or the previous day’s topics. Nicole tends to focus on the correct answer, and does not typically continue discussions after covering one correct method.

Once the warm-up has been completed, Nicole transitions into new material. Sometimes Nicole has the students do an activity, and then take notes. On other occasions, Nicole gives the students notes, and then has the students do an activity to practice the concepts from the notes. Following this session, Nicole has the students begin their homework, usually selected problems from the textbook.

The most noticeable thing for me about Nicole’s classroom was the quiet. The warm-up time at the beginning of the period is the kind of quiet most teachers’ try to obtain during tests. When given time to work in their groups on activities, the noise level did not escalate as in many classrooms. I did notice, however, that some students did not work with their groups, but chose to do things alone, only checking with the other group members when the work was finished. Nicole requires students to raise their hands before answering, and is consistent in reinforcing this expectation. This also contributes to lower noise levels, even during whole class discussions. Nicole herself is a very quiet and calm person. She never raises her voice in class, even when she is reprimanding the class, which happens very infrequently. Generally, if Nicole has to deal with a discipline issue, she addresses the student individually and quietly, dealing with the situation without the other students being aware of the intervention.

Nancy’s Classroom

Nancy’s room also looks like a typical classroom with chalkboards at the front and back of the room, with windows on one side wall and three computers on the other side of the room. The desks in Nancy’s room are arranged in groups of four, and are arranged in such a way that she has students facing all directions.

Nancy has an established a routine in her mathematics classes. Typically, she begins each day with a problem of the day. This problem is sometimes related to a district-wide quarterly exam covering the sixth grade math topics. Other days, the problem of the day serves as a warm-up problem to review the previous day’s topic or to lead into the current day’s topic. This pattern of using a warm-up problem was evident on Nancy’s videotapes made during the program. Following the warm-up, Nancy moves into the day’s lesson. This portion of the class may take on different forms, ranging from group work on an activity, to a whole class instruction followed by group work. Nancy often has students work with their groups. In her videotapes, and during my observations, she frequently has the students brainstorm about an idea with their groups before they share their thoughts with the whole class. She usually has the students work with their table groups when doing any hands-on activities.

Nancy’s interactions with the students are very kind. She thanks students for their responses and often compliments the students on their work. When students misbehave, she gets their attention by moving closer to them and sometimes putting a hand on a student’s shoulder. If this does not encourage the student to stop the offending behavior, Nancy will address the student by name, and make the student aware of the behavior. When the behavior stops, Nancy quietly thanks the students later for responding to her request. During my observations, Nancy made me aware of one particularly trying student and that student’s struggles with many issues outside the classroom. Nancy gave this student a little more latitude in behavior than she usually would have allowed other students. During several observations, this student's behavior was distracting the other students in her group. On one occasion, the student had a mechanical pencil that was not working correctly. The student had taken the pencil apart, and was playing with the pieces, pulling the group members into a game of using the spring from the pencil to shoot other parts across the table. Nancy gently addressed the student, stated that the way the pencil was being used was distracting to Nancy and to the other students at her table. Nancy then asked the student if the pencil could be put back together or if the student was in need of a working pencil, which Nancy offered to provide. The student apologized, accepted a pencil from Nancy, and put away the broken one. The way Nancy approached this student was repeated on other occasions with other students. Nancy tried to use non-verbal signals to redirect students. However, when students had to be directly addressed in a verbal manner, Nancy always did so in a kind way, and made sure the students understood exactly the nature of the infraction. Nancy had written in one of her video reflections that she noticed how loud her voice was. Although her voice does carry easily in the classroom, she does not come across as harsh or yelling. On the videotape and during my observations, the students appeared eager to please Nancy and willing to do what she asked of them.

Lorraine's Classroom

Lorraine's physical classroom differs from the other two teachers' because she has an inside room with no windows. The shape of her classroom is different from a typical classroom. Lorraine's room has many exposed air handling ducts, giving the room a somewhat industrial look. Lorraine's room is large, but the layout creates an annex section that is somewhat separate from the main section of the room. This creates a space that is not really usable, reducing the actual space for the classroom. Two consecutive walls have chalkboards on them, which Lorraine uses frequently. The next wall is an odd design, containing a space used for book storage. The final wall is in the annexed section, with two computers sitting against this wall.

During the year of my observations, Lorraine had the desks in her classroom arranged in groups. The groups in the room ranged from a group of four to a group of six. This was the first year she had tried this arrangement. In the past, she had arranged the desks in rows, although some years she paired the rows, so that the students really sat in groups of two. However, Lorraine did not have the students work as pairs as a regular practice.

Lorraine's manner of interacting with the students is very different from Nancy's or Nicole's. Lorraine believes in dealing with reality and does not encourage students to explain their actions. During one of my observations, a student arrived to the first class tardy. As the student entered the room, the student was carrying a guitar. The student asked for permission to go put the guitar in a locker. Lorraine did not give permission, and reminded the student that the school rules only permitted students' to access their lockers before school, after third period, after lunch, and at the end of the day. The student reminded Lorraine about the late arrival and asked again to leave the room. Lorraine pointed out to the student that the student was responsible for arriving to school on time, and pointed out that it was the student's fault that the student was going to have to carry the guitar until the next permissible locker time. Lorraine consistently puts responsibility back on the students. Although I did not witness any interactions between Lorraine and the parents of her students, Lorraine indicated that she deals with parents in much the same way. She described to me a conversation with a parent who had called to check on a student's grade. Lorraine posts the students' grades at the beginning of each week, and students can access their grades on-line. According to Lorraine's accounting of the conversation, she refused to tell the parent the student's grade, telling the parent that the student should know how to access that information on-line or from the posting in the classroom. This demonstrates Lorraine's consistency in forcing students to take responsibility.

Lorraine's classes do not follow the same routine everyday. Typically, Lorraine begins class by checking the homework from the previous class meeting. Lorraine may not have seen the group the previous day, so the students may have had two nights to complete the homework. Sometimes she reads the homework answers to the class, sometimes she had students share their answers, and sometimes she had students put some of the problems on the board. She did tend to have students demonstrate their work more often in the Algebra class than in the Algebra-Readiness classes. After going over homework, or if there was no homework to discuss, Lorraine would either give the students notes or move into an activity. After going over new material as an activity or by lecturing, Lorraine often gave students time to work on assignments during class. During this time, Lorraine often encouraged students to ask other students in their groups for assistance, but she did answer questions the students asked her. I often observed students off task during this time, talking to other students in a social way. Lorraine frequently reminded students that they should be working in their groups, but she did not provide specific information about how to do that. Her classroom always felt more unsettled than did Nancy's and Nicole's. Lorraine attributed this unrest to the nature of 8th graders. I attribute it to group sizes that are too large and expectations for behavior that are imprecisely stated.

Jonily's District and Building

Jonily was the only teacher in the program from her district. Her district is a suburban district. In the 2001-2002 school year, the building in which Jonily teaches had 560: 80% White, non-Hispanic; 14% Black, non-Hispanic; less than 1% Asian; and less than 1% Hispanic. According to the Ohio Department of Education 2002-2003 school report card, the issues of students with limited English proficiency is not applicable for this building (ODE, n.d.). Although the school is situated close to a light industrial area, the school is immediately surrounded by a large neighborhood of houses. These houses have well kept yards, are larger, and a few years newer than the houses in the neighborhood of Lorraine's, Nancy's, and Nicole's school. There are many mature trees in the neighborhood.

The actual school building is fairly large and well kept. This is a Middle School with grades six through eight. On every visit I made to the school, the hallways were clean and orderly. The office staff was always very friendly and accommodating.

Jonily's Classroom

Jonily's room is larger than a typical classroom, giving her many options for how to arrange the room. In her videotapes made during the professional development program, I saw her seating arranged in several different ways during a single school year. During my observations in her room, I saw the desks arranged in three different ways. Her room arrangements typically group about four students together, either in rows or in a group arrangement. When the desks are arranged in rows, and Jonily wants her students to work in groups, she has the students move their desks so that group members face each other. In those cases, she has the students move their desks back into the starting arrangement before leaving the room.

Jonily is very structured in managing her classroom. She has students keep a warm-up folder, in which they put their daily warm-up problem, notes for the class, activities completed in class, and projects on which they will work for several days. These folders are kept in bins in the room, and students pick up the folders as they enter the room. She is very precise in her instructions, clearly stating what she expects students do to, and how she wants them to do it. During my observations, whenever she had the students work in their groups, she gave the groups a list of tasks to accomplish, and often listed those tasks on the board. At the end of the period, she reminds students to return their warm-up folders, straighten out the desks, and look around for anything out of place.

Jonily has an established routine for how she starts class, with a warm-up problem on the overhead, but not a routine for the remainder of class time. Where other teachers have routines for the kinds of activities, Jonily has more of a routine for her expectations. Some days, the warm-up problem is used as the lesson for the entire period, with students working alone, then talking with their groups, then sharing ideas with the whole class. Some days the warm-up problem serves as a lead into the day's lessons, which might be a discovery lesson, a sharing of student's understanding about a topic, or note taking. Whatever the structure for the day's lesson, Jonily always includes great amounts of student participation and student thinking. Rarely does she answer a direct content question herself. She poses questions back to the students, facilitating the conversation, but not directing it in a guiding way. Jonily consistently encourages her students to take responsibility for their learning by asking questions of her, other students, and other teachers.

Jonily's interaction with students is very kind, much like Nancy's manner. Jonily, and Nancy are clear about their expectations, and neither teacher hesitates to enforce their classroom rules. As with Nancy, Jonily deals with discipline issues quietly and individually with the student. If possible, she moves by the student and talks softly with the student. I observed on a few occasions, Jonily asking a student to stay behind when the class left, but she never said this in front of the entire class. Jonily is clearly concerned with allowing students to maintain their dignity, and does not put students in situations where they would have to challenge her to save face.

Jonily teaches eighth grade mathematics, which means she teaches Pre-Algebra and one Algebra class. There is one other eighth grade mathematics teacher in the building, whose classroom is next door to Jonily's. The two teachers have developed a habit of chatting between periods and eating lunch together. In their conversations, they share ideas and help each other reflect on their daily successes or failures.

Jonily’s daily structure is divided into eight 48-minute periods. The first and eighth periods are a few minutes longer for announcements. Jonily has one planning period and another duty period. During the year of my observations, she was given the duty period off because of other responsibilities she had taken on in the building. The release from the duty period was considered compensation time for the other responsibilities connected to curriculum development. During the two years of the professional development program, she only had one planning period, with her duty period being study hall supervision.

During the year of my observation, Jonily had an Algebra class. The majority of students in the class had also been Jonily’s students in a Pre-Algebra class the previous year. Watching her interaction with these students was very interesting. Jonily commented that she was able to jump right into mathematics with the Algebra class that year because they knew her expectations for discussions. The few students who did not have her last year quickly picked up on the culture of the classroom. Jonily did not need to spend time establishing expectations with this group. She said that the class felt like they were just carrying on from the previous year. Often in this class, students conducted entire mathematical discussions without any input from Jonily. She felt this happened because of their experiences with her the previous year. I was impressed with the kinds of discussions Jonily encouraged from her Algebra I and Pre-Algebra students. I frequently found myself wondering how much further along in their mathematical thinking those

Pre-Algebra students would be if they had been in Jonily's classes for two years, as had the Algebra students.

Summary

All four teachers in this study share some similarities and differences. Both schools had parents who were actively involved with their children's school lives. Lorraine, Nancy, and Nicole all commented on feeling constrained by the district's mandated curriculum, while Jonily felt she had the freedom to structure her content in any way she deemed appropriate. All four teachers expressed feeling a freedom to deliver material in any manner they desired. Nancy, teaching 6th grade, and Jonily, teaching 8th grade, interacted with their students in similar ways. Lorraine often commented that some of the things she wanted to do would not work because of the nature of 8th grade students, an indication of her different way of interacting with her students. Nicole's classroom was the most predictable, as far as the activities and progression through a lesson. Nevertheless, all four teachers had some predictable patterns to their daily classes. None of the four teachers had any serious discipline problems arise in their classrooms while I was there, and none of the four talked about discipline as a factor for consideration when making decisions about lesson delivery. Although they interacted with their students differently, whenever one of the four indicated a boundary for students, the students took the boundary seriously and did not challenge the teacher. I provide these details to help the reader understand that these teachers were all comfortable with who they were as the teacher in the classroom and were able to establish a presence in the classroom, although each established a somewhat different presence.

CHAPTER 5

PORTRAITS OF CHANGE

The purpose of this chapter is to examine the changes to teaching practices that the teachers made during and since the two-year professional development program, the *The Teacher-Researchers: Making a Difference in Mathematics Teaching and Learning Through Inquiry* (Pape, 2000), and to explore the teachers' motivations for making those changes. The identified changes fall into three categories: changes the teachers identified as having implemented, changes that I identified as the teachers having implemented, and changes the teachers identified as intending to implement at some future time. In this chapter, I will also examine sustained changes that I observed in the classrooms, in order to understand why the teachers were committed to those changes. Un-sustained changes and changes intended for the future will also be explored to understand the teachers' struggles with those practices. Each teacher will be presented as a separate case study.

As a note for the reader, I should explain the how student's comments are referenced in this and subsequent chapters. My agreement with the school districts in which I observed stated that no students would be identified nor would one be able to identify individual students in the data collected. To be true to this request in my field notes, I have only identified students here by referring to them as Student 1, Student 2, and so forth. Student 1 is simply the first student who talked during the conversation.

Any subsequent contributions to the conversation by that student refer to that student as Student 1. Please note that Student 1 from one conversation is not necessarily the same student as Student 1 in a different conversation. The reader should be mindful of the referencing system when reading any transcribed dialog.

Nicole

The kinds of changes and the nature of sustaining those changes are in some way very similar and in other ways very different between the four teachers. Although Nancy, Nicole, and Lorraine all teach in the same building, they teach different grade levels and have different personalities. Their needs when they entered the program where also different. When asked about the changes she had made to her teaching practices, Nicole first offered questioning as the biggest change. She identified this as the biggest change because it was the topic for her research project (October 28, 2003, Preobservation interview). After analyzing the data, I concluded that what she identified as changes in her questioning practices were actually a set of changes centered on classroom discussions. These changes include a change in the frequency of discussions in her class, changes in the part of the class where discussions were utilized, and changes in the kinds of questions she asked. Connected to that set of changes, Nicole also made changes in how she incorporated group work and journal writing in her classroom. Perhaps the biggest change that Nicole made was in her thinking about mathematics and teaching mathematics. This shift in thinking actually facilitated the other changes that Nicole made and will start the analysis of Nicole’s changes.

Nicole's Changes in Thinking about Mathematics and Teaching Mathematics

When Nicole entered the program, she was interested in finding good activities to use in her classroom. She wrote, "I have read and heard a lot about mathematics reform but have had little help implementing the ideas. I want to learn practical ways to implement these theories" (Summer 2000, Bio). She wanted "to learn more innovative ways of teaching math concepts. What are some authentic ways to teach the distributive property, for example" (Summer 2000, Journal 1). Her main focus area was to find concrete things to use in her classroom. She even went so far as to write, "I want to learn about educational theory and effective practices, but it is useless if I am not able to implement the ideas and practices in my classroom" (Autumn 2000, Journal 4). Although she was focusing on things to carry into the classroom, she indicated an awareness of improvements she wanted to make in the use of questions:

> I want to begin to incorporate more discourse in my classroom. I typically use guiding questions and student questions in teaching math. I need to incorporate more student-to-student discussion. I need to allow the time and opportunity for student discourse (Summer 2000, Journal 1).

As Nicole progressed through the program, she broadened her idea of what she wanted to gain from the program and expanded the kinds of changes she wanted to make. After the first summer course, where much time was spent looking at the mathematics standards for the state of Ohio (ODE, 2002) and the *Principles and Standards* (NCTM, 2000) she began to express ideas that indicate she was beginning to embrace some of the philosophies behind those standards. At the end of the first summer, when asked what she had learned in this course that she believed would change her teaching, she wrote: “Ways to discuss/dialog. Beliefs on how children learn” (Summer 2000, Class Evaluation). In the category of beliefs about how children learn, she was beginning to understand the difference between teaching procedurally and teaching for conceptual understanding. She wrote, “I do not want students to simply learn the way I solve problems, but I want them to understand the concept” (Autumn 2000, Journal 1). This new information was overwhelming to Nicole. Although her understanding of standards-based mathematics was growing, she was still immersed in the concrete, practical applications of those ideas and not processing the larger, philosophical ideas.

> Yeah, but still it's kind of overwhelming. There's so many things I want to do. Just like—where do you start. My questioning—I want to have them write more. I want to do more projects. I want to do portfolios. There's just so much. That's why I probably haven't changed that much because I don't know where to start (Winter 2001, Focus Group).

In Autumn 2000, Nicole elaborated on her growing belief about students’ developing conceptual understanding by focusing on student thinking. “Learning one way, the teacher’s way, is not adequate for teaching math concepts. Oftentimes students have a wonderful way of thinking about concepts and their thoughts should be shared” (Autumn 2000, Journal 2). Nicole expressed impatience with student discussions and acknowledged that she often guided the discussions herself (Summer 2000, Bio). Even through this conflict, she continued to pursue the use of discussions in her classroom. Nicole’s early thoughts on discussions in the classroom focused around answers to problems and having students explain their work. When she first selected improving discussions as a goal, she noted that, “Most students are still just concerned with getting the right answers and are unsure of how to communicate how and why they solved it as they did. (Autumn 2000, Journal 3). Notice how this comment reflects her newly developed belief that students should see more than one way to do a problem. At the same time, her emphasis on students’ thinking about solving problems reveals that Nicole was still promoting mathematics as procedures. While this focus appears to conflict with her statement about wanting the students to understand concepts, I think it actually reveals her interpretation of what conceptual understanding looks like. Nicole was just beginning to understand the big picture behind the reform movement, and one of the changes she was making at this point was a subconscious adjustment of her beliefs about what it means to understand and talk about mathematics. One year into the program, Nicole wrote:

> I understand the basics of helping students develop a conceptual understanding. Procedural understanding is helpful, but by itself it is not enough. Students need to be given opportunities to apply and develop understandings based in real world contexts. Mathematics is not just a set of rules or principles but it is a way of knowing and thinking . . . . I think I have known the basics, but I am learning what it means to apply them (Summer 2001, Journal 2).

After being in the program for a year, discussing and exploring reform-minded practices, Nicole was starting to understand that knowing mathematics in a procedural way was insufficient. In a later journal response that same summer, one year after entering the program, Nicole wrote, “I believe I am still in the pupa stage. I have aspects of a behaviorist and constructivist practices in my teaching” (Summer 2001, Journal 4). The year spent in the program had introduced her to a broader picture of mathematics, but she was still transforming herself. Her idea of constructivist teaching was still vague and unformed. Note how in the following quote she listed specific steps she would take to plan a lesson, but was vague about how to incorporate constructivism into her classroom.

> I don’t rely on the book when it comes to teaching a concept. I want to go through all my books and resources for ideas on how to best teach a particular concept. I try to find the best way, activity that will help students understand the concept. Help students understand the concept which I cannot find an activity or idea. I sometimes rely on more constructivist ways of teaching (Summer 2001, Journal 4).

Teaching with a constructivist philosophy was a novel idea to Nicole; she had never experienced those ideas as a student nor as a teacher until entering the professional development program. She was beginning to understand this approach to teaching mathematics, and was just beginning the process of understanding how her practices differed from this new idea.

Initially, she seemed to equate discussion in the classroom with teaching in a constructivist way. A probable explanation for this rests in the construction of the classes during the first year. During the first two quarters of the program, many of the readings in the class focused on discourse and student thinking. Much of the discussion in the class was concentrated on establishing norms for the classroom, including discussions about how to have students talk about mathematics. Also, during the third course, which was more content oriented than the first two quarters, much of the discussion focused on the kinds of questions the professors asked during mathematical activities done in the class and how the professors had facilitated the discussion. Although many other topics were integrated into the course, the interest of several members of the class often influenced the discussions toward connections to discourse. Nicole cites Nancy as having been influential in helping her decide to focus on discussion (October 28, 2003, Preobservation interview).Therefore, Nicole's focus on discussions in her own classroom is very understandable given the influence of the program. However, the fact that she equated discussions with constructivist teaching seems to be more a reflection of an incomplete understanding on her part.

Nicole's Progression from Discussions to Questions

While Nicole was beginning to understand how a reform classroom might look and feel, she was taking active steps to improve discussions in her classroom. Looking at her comments, when Nicole first said she wanted to improve discussions in her classroom, what she actually meant was that she wanted to increase the frequency of discussions. As noted earlier, she began by having students explain their solutions to problems. One of the early struggles she encountered was having students use "the correct language when they disagree with a student and not making fun of each other when the answer is 'incorrect'" (Summer 2000, Journal 3). However, in her videos taken between September 2000 and June 2001, there are no instances of students teasing each other during the large group discussions. This seemed to be more of a problem for Nicole as she began to use small groups and not so much a problem during whole group instruction.

In two different journal responses, Nicole indicated that her students tended to focus on getting the right answer. (Summer 2000, Journal 3; Winter 2001, Journal 3). She implied in these two journals that she was trying to have students explain their thinking more often. She wanted the students to explain how they arrived at their answers and not just state the final answer. However, Nicole herself often focused on correct answers, reinforcing for students that the answer and not the thinking was important. The following two discussions demonstrate a common tendency of Nicole's during the first year to focus on correct responses while deemphasizing the students' thinking.

Discussion 1—Going over the Problem of the Day. Problem B was to decide if two ratios were equivalent.

Nicole: What about B?

Student 1: Yes it is

Nicole: Is 1/8 equal to 125/1000?

Student 1: Yup

Nicole: Well, Student 2, can you divide that for us? Do 1 divided by 8.

Student 2: 0.125

Nicole: So that one's equal—1/8 is equal 125/1000?

(November 15, 2000, 4/5 block, Video)

In Discussion 1, Nicole does not ask how the student decided on yes. Once Nicole heard the correct answer, she went on to walk the class through the process for getting the answer. In the next discussion, later in the year, Nicole did ask some students to explain their thinking. Notice that she asked a student who had the correct answer to explain and did not ask any students with the incorrect answer to explain how they arrived at their answers.

Discussion 2—The students had measured the length and width of rectangles that were printed on paper. The students were then to decide how to group the rectangles, so that rectangles with the same ratios were together.

> Nicole: Let's pick another group. Student 1, what do you get?
>
> Student 1: H, C, and D
>
> Nicole: Well, let's look at these. Here's H, C, and D. Does everyone agree with that?
>
> Students: yea, no, no
>
> Nicole: Let's hold it up like this and see if that helps us see anything. [She holds up the rectangles, one on top of the other.] Raise your hand if you think these three are a group.
>
> [some students raise their hands.]
>
> Nicole: So about half the class. OK, if you don't think they're a group.
>
> [some students raise their hands.]
>
> Nicole: OK, someone who doesn't think they're a group, tell me why. Student 2?
>
> Student 2: C and D are too close together.
>
> Nicole: These are too close together. What do you mean?

Student 2: They're like almost the same size and then H is like way, way, way bigger. I think A is the other one.

Nicole: You think A goes with what?

Student 2: I think A is the little one and then H is not the big one.

Nicole: You think A goes with C and D.

[other students say which three they think go together]

Nicole: What do you think gentlemen?

Student 4: (inaudible)

Nicole: Well, how could we find out for sure?

[one student has a discussion with Nicole about the orientation of the rectangle]

Nicole: Well, how could we find out for sure if we can't tell by looking?

Student 5: Measure them.

Nicole: What told us they went together for sure

[They then went on to calculate the ratios of long side to short side for each of the rectangles to find out that H, C, D do not have the same ratios.]

(March 14, 2001, 7/8 block, Video).

Examining these two discussions provides evidence that Nicole was making progress in increasing the frequency of discussions in her classroom. Not only was she using student input to go through the procedures of problems, but she was also incorporating student explanations in lesson material.

During my observations in Nicole's classroom, she facilitated many discussions. The discussions she facilitated focused on homework, the problem of the day, activities to introduce new ideas, and sharing students' prior knowledge during notes and demonstrated her continued commitment to the improvement of discussions in her classroom. One discussion that I observed was clearly student driven. This discussion took place on November 17 in her 4/5 block. To introduce solving multi-step equations, Nicole had the students participate in a magic number activity. Each student independently chose a starting number and Nicole led them through performing operations on the number. At the end, all the students arrived at the same answer, independent of their starting number. After several rounds of this, Nicole asked the students to raise their hands if they could tell her why they were all getting the same answer. One student asked her if it mattered whether they started with even or odd numbers. Nicole asks a few students what they started with and what they ended with. After soliciting several examples of even and odd starting numbers, one student offers an explanation of why the answers might be the same. The student who originally brought up the discussion indicated disagreement with the explanation. Nicole then suggested they all do an even and an odd together to see what would happen. After doing several examples, one student suggested that they try to model that problem without using specific numbers. Nicole then walked the class through a model. When asked if she was uncomfortable if students go in a direction that is unclear, Nicole said:

> But that's why I like teaching math because I usually know—like when I student taught I had science and there's so much science that I forgot. That's why I like math because I can usually figure it out but sometimes yes. I think when I don't understand their thinking it stresses me out because I can't really help—if I don't

> understand what they're—because I think of it in a different way. It still stresses me out. I'll admit to them if I forget or something but I still wanted—like if the kids are talking and I know they understand but I don't understand their thinking it still stresses me out because I can't help em. I can't help the other kids understand what they're thinking. (Winter 2001, Focus Group)

Her inability to provide immediate assistance to her students clearly caused stress for Nicole. This may be an indicative of her views of the teacher as the mathematical authority in the classroom; because she is supposed to be the authority, she expects that she should always understand their thinking. Not being able to understand her students threatens her position of authority.

Because of Nicole's struggle, she began looking for practical things she could do to improve the discussions. Late in the first year of the program, Nicole changed her focus from improving the discussions in her classroom to asking better questions. Nicole noted late in the first year of the program,

> I noticed that I do ask a lot of questions, but I can work on improving the types of questions that I ask. I ask a lot of recall questions, but I do tend to ask many how questions or have students tell me how they solved the problem. However, I tend to stop it there when I agree or disagree with them I think I need to work on this from the first day of school to establish this type of environment. (May 24, 2001, Video Reflection).

Still frustrated by the quality of the discussions in her classroom, she felt that improving the type of questions would lead to "more dialogue in my classroom, more reasoning, and more participation" (Spring 2001, Journal 3). Nicole attributes the realization that she could improve the type of questions she asks to the support person who worked with her. With the efforts of her support person, Nicole decided to research the level of questioning and the students' responses to those questions.

At the end of the first year, Nicole began to plan a change for the following school year. She planned to ask better questions and to expect more participation from her students. "If students are expected to participate in a class discussion from the beginning of the year, I believe I will get more student involvement" (May 24, 2001, Video Reflection). In watching the videos of Nicole's classes, and during my observations, I did observe Nicole asking questions that were of a level higher than recall. Using the original Bloom's Taxonomy (Krathwohl, 2002), I would categorize the majority of Nicole's questions as knowledge, comprehension, or application.

During my observations, I observed Nicole asking analysis level questions in one instance. This was in the student-generated discussion about the relevance of starting with even or odd patterns, a discussion presented previously in this chapter. On another occasion, I observed Nicole asking synthesis level questions. During my observation on October 1, 2003, in the 7/8 block, Nicole began the lesson about integer subtraction by modeling simple subtraction problems. For example, she demonstrated that the problem such as $3 – 2 = 1$ as three plus signs and two minus signs. She then demonstrated how two of the negative signs join two of the plus signs to create zero, leaving one plus sign. The examples then moved on to a positive minus a negative and a negative minus a negative. She demonstrated adding in zeros by adding one positive and one negative.

After 4 examples, Nicole put up another problem involving a positive number minus a negative number. Student 1 said, “If you just add it, you get the answer.” Nicole told the student to keep thinking about that idea, and completed the example using the concrete model of the positive and negative signs. After completing the example, Nicole asked Student 1, “Does your method still work?” Before Student 1 could respond, Nicole told the class that they would do one more example and then work with the idea more the next day. She then wrote (– 6) – 2 on the overhead. Student 1 offered negative eight as a prediction to the answer. Nicole asked, “How did you predict it?” Student 1 responded with “I don’t know how to explain it.” At that point, the bell rang and Nicole had the students put away their math and take out their Health books. She ended the discussion by reminding the students that they would work on this idea more the next day. I had the impression that Nicole did not realize the potential learning experience that could have resulted from pursuing this conversation. She appeared to view Student 1’s comments as an interruption instead of a launching pad for a deep, mathematical conversation.

After experimenting with the use of higher level questions, Nicole noted that it was difficult for her to ask good questions unless she planned them ahead of time (November 29, 2001, Video Reflection). After concluding her research, she seemed to have modified her goal from increasing the number of higher-level questions. Instead, her new goal was to including a few higher-level in each lesson. Instead of thinking that all of her questions should be more intense, she now seemed to settle for a few good questions.

> And I found out doing my research that all your questions can't be higher level questions because you have to build up to that and you have to—and for time. So I just try and incorporate a couple in the lesson (October 28, 2003, Preobservation Interview).

Issues Limiting Nicole's Progress With Discussions

Nicole's lack of enthusiasm for higher-level questions after her research is not surprising to me. First, exploring higher level questions takes more time on the part of the students and requires that the direction of a lesson be somewhat flexible. Nicole demonstrates a dedication to completing her daily plan for a class, regardless of how the lesson progresses. This prevents the required flexibility. Also, Nicole's knowledge of mathematics tends to be procedural, or calculational (Thompson, et al., 1994), making the construction of higher level questions difficult. If the mathematical information is not well connected in Nicole's understanding, this level of thinking would be difficult.

Nicole's Need to Complete her Daily Agenda

Although Nicole successfully increased the frequency of discussions in her classes, Discussion 2 demonstrates her focus on correct answers. In Discussion 2, Nicole only asked for explanations from students who had the correct answer. This decision can be explained, in part, by her commitment to getting through her agenda for the class. In a written reflection on the video of her lesson introducing scatter plots, Nicole writes, "The time factor had a large impact on our amount of discussion, but I need to organize my lesson to allow plenty of time for discussion" (November, 30, 2000, Reflection of Videotape). This response reveals that time influenced her decision to allow discussion, showing that she wanted to complete her plans that day for the class. In a written reflection on one of her videotapes, Nicole commented that "I felt like I had to rush through the lesson, and therefore, I believe I asked very leading questions. There was not enough time for the students to really explore and discuss and I think I ended up just telling them how to solve the equation" (February 22, 2001, Video Reflection). Although she was feeling that the lesson was not going as she wanted, she did not alter her plans for the day. On another occasion, Nicole commented on her wait time:

> I also noticed that my wait time is not long enough when I ask questions. I guess I get uncomfortable with the silence or do not like to "waste time" so I tend to either re-ask the question in a more leading way or answer it myself. (February 22, 2001, Video Reflection)

This quote demonstrates Nicole's desire to control the speed of things in her classroom. She clearly had in mind a goal for the class, and worked to move students to that point. Although Nicole became aware of this problem, none of the evidence from the two-year period of the program indicates that she focused on changing this practice.

My observations in Nicole's classroom also provide evidence that she has not yet discontinued the practice of controlling the agenda for the class. During my November 19 observation, there was chaos in the building. At the beginning of the class, there was much noise coming from the hallway. Without making any comments about the noise, Nicole shut the door. The noise was still disruptive even with the door closed, but she did not say anything to the students. After this noise, an announcement was made calling for students with picture retakes. About the same time, a train with the whistle blowing went up the tracks outside the open window. Later in the same class, a large group of visitors entered the room and moved around the room for a brief time. Nicole did not say anything to the visitors, nor did she say anything to the students, but instead continued to circulate to the groups as they worked on their activity. The group of visitors was in the room for about 5 minutes. Approximately 10 minutes later, while Nicole was starting to give the students notes on the topic, another large group of visitors entered the room. Nicole continued with her lesson as if nothing had happened and clearly expected the students to do the same. As I sat in the room, I experienced a great discontinuity in the lesson; I was often distracted. In my field notes, I wrote "I wonder what the kids got out of this lesson?" (Observation November 19, 2003, 4/5 block).

This crazy day exemplifies Nicole's habit of not modifying her daily plans. Once she had established the daily agenda in her mind, not even extreme disruptions could prevent her from completing that agenda. While not allowing students to derail the day's plans is commendable, Nicole almost carried her commitment to her plans to the other extreme. She is not using feedback from her students to make immediate modifications to her plans. I did see evidence that she rethinks her plans for the next day at the end of a class, but she does not appear to be making changes to a lesson in the middle of a lesson.

This need to complete her daily plans is probably just a symptom of bigger, underlying issues connected with Nicole's beliefs about the role of the teacher, beliefs about teaching mathematics, and beliefs about mathematics itself. The combination of these beliefs, Nicole's past experiences in mathematics classes as a student, and her own mathematical knowledge all contribute to the creation of this need for control over the daily agenda. The interactions of those issues are complex and made the dissection of individual contributions nearly impossible. The resulting symptom, however, was clearly evident in the data and served as an indicator of larger ideas with which Nicole will have to grapple before she can make further progress.

Nicole's Incomplete Mathematical Knowledge

Nicole's incomplete knowledge of mathematics is also a contributing factor limiting the change she could make. Nicole did well in high school mathematics, having earned all A's because "they teach it, I memorize it and then do it and I could always do it for the tests and stuff" (January 14, 2004, Final Interview). At the college level, she only had one mathematics course, Calculus. About that course she said, "most of it was over my head because I wasn't used to thinking why. I just said, ok you do this, you use this step . . . ." (January 14, 2004, Final Interview). She said that she struggled in Calculus because "I had to think about it more so I think I would have done better in college if I really understood the math rather than just memorizing" (October 28, 2003, Preobservation Interview). While in the program, some of the courses were focused on mathematical content and in all of the courses the participants were doing mathematical activities. Through those experiences, Nicole's knowledge of mathematics increased:

> I know through the program I learned some things. I learned some concepts. I always knew how to do it but maybe I made some connections or something. I know how to do seventh grade math. I can do it but I think it just really got me to think more about the different concept (October 28, 2003, Preobservation Interview).

Given this evidence of an incomplete understanding of the mathematical content, Nicole is likely to continue her struggle with facilitating student-centered discussions. Asking questions that build on students' thinking and helping students pull together threads of ideas requires a complete and well connected knowledge of the mathematics on the part of teacher. Part of Nicole's reasoning for wanting to improve the discussions in her classroom centered on students learning more than one way to solve a problem. Even though she wants students to hear different ways to solve problems, she often implies that there is a best way. She asks, "Was that a good way to solve the equation? Why or why not?" (Observation, November 17, 2003). "Was that the most efficient way?" (Observation November 18, 2003, 1/2 block).These questions give students the subtle message that problems have a correct way to be solved and reveal something about Nicole's mathematical understanding.

During my observations, I saw one discussion that really built on student thinking. That discussion was about algebraic procedures to solve equations, with which Nicole is likely to be comfortable given her procedural understanding of mathematics. If she had more conceptual understanding of other topics, she would be more comfortable allowing student discussions and explorations during other lessons. Currently, she is lacking many of the connections and the flexibility she would need to see her way through these student-directed discussions (Borko & Putnam, 1996; NRC, 2001). Consequently, Nicole continued to struggle with facilitating discussions.

In order to achieve her goal of increasing the frequency of discussions in the classroom, Nicole began to use groups more often. She felt that having student work in groups would help students feel successful because they might be able to contribute to effort assigned to the group (Winter 2001, Journal 4). In the preobservation interview, Nicole said that having students move into groups was one of the suggestions offered during the program for helping students learn to give better answers. One of the changes Nicole made involving groups was to establish groups at the beginning of each quarter. "In the previous years I would assign groups each time we did an activity or when I wanted them to work together in a small group" (Autumn 2000, Journal 1).

Nicole's Changes in the Utilization of Groups

During my observations, Nicole made frequent use of the groups. Some activities were stated specifically as group work. For example, the students did an activity matching mathematical inequality statements to word descriptions of a situation and the students were told to work in their groups to match the statements and the inequalities (Observation November 18, 2003, 4/5 block). At other times, the students were instructed to work individually but to consult with their group if a question arose. In almost every lesson I observed, Nicole had the students do something with their groups. Nicole keeps her classroom in rows. When she instructs students to work in groups, some of the groups rearrange their chairs to form a group. Other groups leave their chairs in rows and turn their bodies to face each other when they need to talk to their group members. After each group activity, Nicole always instructed the students to rearrange their desks back into rows.

Although she is using groups frequently, there is evidence that she had not totally bought into the principles of cooperative learning. The fact that she does not ask the students to form a group physically with their desks indicates to me that she has not considered the subtle dynamics involved during group work. She infrequently used the group discussions as starting points for whole class instructions. She referred to the activity that the group performed, but she did not incorporate the discussions that groups had about those activities. Once the class finished their group work and they returned to a whole class environment, I did not observe Nicole asking the groups to reconvene to further discuss ideas that surface during the whole class instruction. Nicole has been presented with the concrete action of group work but she has yet to understand the complete implications of using groups in reform-minded ways.

Nicole's Changes in Journal Writings

The final change in Nicole's teaching practices was also a result of her search to improve discussions. Because she had concluded that she could not ask more higher level questions, she has decided to include some extended response questions periodically (October 28, 2003, Preobservation Interview). The students answer these questions in their journals and share their writing with the class. Nicole also has the students do many of their lab activities and other kinds of writing in their journals. While I was observing, Nicole used the journals frequently for lab-type activities but did not have the students complete any extended response questions. In an informal conversation about the journals, Nicole said that she had a few extended response questions selected for different units, but not for every unit.

Nicole's Future Changes

Regarding changes that Nicole hopes to make in the future, she stated one specific goal, incorporating "Math Court" into her classes. She was introduced to the idea of "Math Court" by a teacher in the district and wanted to implement the idea in her classes. Math Court involves the students giving explanations and defending their explanation (October 28, 2003, Preobservation Interview). Nicole liked the idea "because that's a different way of helping them with explaining, other than just trying to write out—because still a lot of them don't see why their answers aren't clear, their writing isn't clear" (October 28, 2003, Preobservation Interview). She did not have any definitive plans for when or how she would implement the idea. I propose that Nicole was attracted to the idea because, once again, it offered a concrete way to implement the reform-based changes she thinks she should be implementing. I do anticipate that she will have some trouble with the implementation, because of how she understands the mathematics content herself. Helping student learn to assess the validity of mathematical arguments will require that Nicole is comfortable with different kinds of arguments and the mathematics behind those arguments. I foresee that students who stray from an expected kind of answer will present a challenge to Nicole.

Nicole does have plans to take more mathematics classes, which will combat this limiting factor. She is participating in a discovery-learning advanced-level mathematics class this summer. She has also expressed interest in taking additional mathematics classes in the hopes of becoming certified to teach secondary mathematics.

Summary of Nicole's Changes

Ultimately, Nicole made many changes, some in her thinking and some in her actual practices. Nicole progressed gradually from wanting to find good activities, to wanting to improve the discussion in her classroom, and finally landed on asking better questions. This progress represents long-term development and was by no means a pre-determined course on Nicole's part. Simultaneous to this long-term progression, Nicole was collecting ideas that I classify as concrete actions. She wanted to change things in her classroom in a quick, obvious way and was consciously trying to reform her classroom by immediately taking action in these concrete ways. Some of the actions she implemented involved using groups, and problems and activities that were presented in the professional development program.

As a subtle under-layer to Nicole's conscious efforts, she was experiencing changes in her mathematical knowledge and her understanding of the principles and philosophies behind the reform efforts. Although Nicole still feels like she has a long way to go, her use of reform language in comparing where she is now and where she wants to be indicates an awareness of how her classroom differs from that of a reform-based classroom. As Senger (1998-1999) explains, this use of language without accompanying actions may represent a "trying on" of new ideas which may be followed later by action.

Nicole had three issues that limited her potential for progress towards a reform-based classroom. The first limiting factor involved the beliefs underlying Nicole's need to complete her daily plans as scheduled. These beliefs included ideas about the structured and orderly nature of mathematics, and the nature of learning mathematics.

Her views about the nature of mathematics also influenced the way she created a mathematical authority in her classroom, and how she encouraged students to view her as that authority. Until these beliefs are challenged, Nicole's teaching practices have limited potential for change.

The second limitation was her knowledge of mathematical content. Her knowledge of mathematics is procedural, which limits the connections she can make between concepts. Accomplishing a reform-based classroom rich in mathematical discussion and student participation requires strong content knowledge on the part of the teacher. If Nicole does not continue her efforts to improve her own content knowledge, the amount of change she can make is somewhat limited because her content knowledge prevents her from making connections between topics. She will also continue to be unable to generate good questions that challenge the students thinking for the same reason. She is willing and interested, though, in taking more mathematics classes which can help her conceptual understanding and procedural fluency.

The reform-efforts Nicole has implemented so far in her classroom could have provided the necessary challenge to her existing beliefs, but have not so far. Right now, she seems unaware that her beliefs about mathematics, teaching mathematics, and mathematical authority are in conflict with the changes she has attempted. The next step for Nicole will be to experience some conflict between her beliefs and the actions she wants to take, and to explore the implications of those conflicts.

Nancy

Nancy’s growth during the professional development program was very different from Nicole’s. Nancy’s comments about her goals and desires for students in her classroom remained very consistent over time, changing very little from the beginning to the end of the program. Nancy offered almost the same statement at two different times four years apart: she wanted the students in her classes to be excited about math and to be confident in their ability to think mathematically (Summer 2000, Journal 1; January 22, 2004, Final Interview). These comments are consistent with the classroom environment that was evident in all of Nancy’s videos and during my observations. Nancy’s practices and espoused beliefs appear to have been closely aligned with the NCTM vision even before she entered the program.

Initially, I had trouble identifying changes in Nancy’s teaching practices because of this firmly entrenched teaching personality. As I examined the data, I realized that Nancy’s teaching practices did change, but in more subtle ways than did some of the other teachers. After watching her videos, I spent several days in her classroom observing her in an effort to get to know Nancy better. During my first day in her classroom, I was impressed with the atmosphere, but was struggling to identify any major differences between her classroom then and her classroom captured on video. My struggle continued even after several days of observations and through my first interview with Nancy. It was not until I began to scrutinize the data that I understood the important but subtle changes Nancy had made.

On the surface, Nancy had already established a reform-minded classroom. The environment had already been inviting and students were willing to take risks in her class even in the earliest videos. Nancy had been using reform-minded practices such as groups and hands-on activities, and had been asking good questions. However, her reasons for using those things were not always in line with standards-based teaching, and her understanding of how to fully implement those practices was incomplete.

Nancy first entered the program because she was attracted to the idea of working on a masters degree in the area where she had spent about sixteen of her twenty-one years in teaching, and because the idea of working with teachers from the other grade levels in her building was appealing. Nancy said that the ideas and readings in the first class "really clicked with me" (Winter 2001, Focus Group), keeping her committed to completing the program. Nancy is a teacher who wants her students to become confident and enthusiastic about mathematics. When asked what she perceived her job as a mathematics teacher to be, she responded: "To make kids excited about math. Make the kids believe that they can think mathematically and for kids to see math as something that's valuable in their life" (January 22, 2004, Final Interview). This commitment to students' enjoyment of mathematics stimulated her early decision to pursue discourse as a focus for change in her classroom. Early in the second class, Nancy wrote, "The element of my teaching that I would like to change is my style of questioning students, responding to students and discourse" (Autumn 2000, Journal 1). Discourse became a pervasive element in Nancy's classroom, permeating every aspect of instruction.

In her endeavor to create a discourse rich classroom, Nancy made the following changes: incorporation of student-directed discussion, shifting of mathematical authority, utilization of journals as a thinking tool, identification of constructivist activities, and improvement in the use of groups. As part of her changes in student-directed discourse, she also made changes that included the establishment of norms for discussions and modifications of her questioning techniques. In the next section, I will discuss how Nancy made each of these changes.

Nancy's Changes Related to Student-Directed Discussion

As one of her first steps in incorporating student-directed discussions, Nancy implemented the habit of taking explicit steps to establish classroom norms surrounding discussions. One of Nancy's norms was that every student should participate in discussions. To better facilitate this, Nancy began using journal writing to increase the processing time for students so that more students could participate in the subsequent discussions. Nancy also made changes in her questioning techniques which served to remove her as the sole mathematics authority in the classroom. In conjunction with using questions in a different way, Nancy also began to focus on finding better activities or to modify existing activities to bring more of a constructivist approach to her classroom. Finally, Nancy improved the way she was using groups. Discourse became a pervasive element in Nancy's classroom, permeating every aspect of instruction. These distinct yet interconnected changes allowed Nancy to create that environment.

Nancy became interested in the discussions in her classroom because of the readings and conversations in the first class of the program (Winter 2001, Focus Group).

The inclusion of discussions in her class was an instantaneous change for Nancy. Once Nancy decided to incorporate more discussion in her classes, she began to have students share their thinking in almost every lesson (January 22, 2001, Debbie White's observation notes). Nancy described the excitement she felt with the change:

> When I started to use in my classroom the idea of the discussion, that really took off for me this year and by that I mean I tried a lot of the things with when the kids give an answer instead of just one kid answering and saying yes that's right I've done a lot with "what do you think the answer is." Do you agree or disagree with that? Support it, justify it. What has happened is the kids have gotten used to that as a norm in the classroom. It has drawn kids in that normally sit there and pick out the smartest kids in the class and always let them answer. Because there's lots of people answering every question and putting lots of answers on the board, a lot more kids have participated and so I've really taken on with that and really used that a lot and I've actually even structured some of my lessons to be specifically with that goal in mind… (Winter 2001, Focus Group)

Because Nancy started using rich class discussions before she started video taping her classes, this immediate change was not apparent in the videos and explains why I did not initially identify this as a change.

Simultaneously, Nancy made another change that some of the other participants did not accomplish. Nancy understood that student discussions would not spontaneously occur and that she was going to have to establish some expectations in her classroom. During the class, the participants talked about how to establish norms for classroom discussions and Nancy decided to implement those ideas during the school year. Nancy established norms regarding respect and participation. In her own words:

> The social constructed norms that are in place in my classroom include two main categories. The first norm is one of mutual respect for each others as learners and as people. Students expect to treat each other and myself with respect. They also understand that there is an expectation of listening to the speaker whether it be another student or teacher. The second norm includes an expectation that all learners will participate in the learning of mathematics in the classroom. They do this by engaging in activities, table group discussions, and whole class discussion. (Autumn 2000, Journal 3)

In watching Nancy's videos, these norms are evident as part of classroom practice even in her first video. Having interacted with Nancy, I suspect that these norms had been in her classroom to some degree for many years, having been created unconsciously by Nancy in the past. However, what did change was Nancy's awareness of the need for explicit reiteration and practice of those norms. Nancy was now more conscious of the need to make these expectations explicit to her students.

The next step in changing her practices was her realization that she had to establish norms. Making and establishing norms was a very natural part of teaching for Nancy. However, through the program she realized that she would have to periodically revisit these norms with the students to help students learn and understand her expectations (December 7, 2000, Review of a videotape math lesson). She felt that the first year of explicitly establishing norms and using classroom discussion was very successful and wanted to continue the practice. However, when she began the second year, she felt like she was failing:

> When I went through the first year of doing that with a group of students, going from September to June it was really difficult to get to the point where I was good at questioning and getting that conversation to take place and the kids needed to learn how to do that. Then by the time we got to the end of the school year it's like oh wow, they're great at this. Then when the next year school year started I thought oh my gosh this is terrible. This group isn't going to be able to do it. I'm not any good any more. Then I realized that not only did I have to know what I was doing but I also had to help the kids. They didn't come to me already knowing how to do that unless they had been exposed to somebody that used a lot of that discussion techniques in the past. Especially with the way that we talked about math and agreeing, disagreeing, justifying their answers. So I had to train them all over again. I remember reflecting for Dr. Pape this group is not going to be able to do it. I am frustrated, the whole bit and then getting further in that year realizing okay, every year, every group can do this (January 22, 2004, Final Interview).

The establishment of norms necessary to conduct student directed discussions is still an active part of Nancy's classroom. Although I did not observe Nancy's initial conversations with her classes during which she established the norms, I did observe Nancy frequently reminding students what she expected from them. Nancy has several methods of reminding students that she expects everyone to participate. During my observations, Nancy circulated around the room while groups discussed ideas. When Nancy stopped at a table, students would brief her on the group's discussion. When a quiet student offered an example or an idea, Nancy would frequently ask that student to share the example during the large group discussion. Nancy reinforced the norm of listening to other speakers by saying things like, "Excuse me, [Student], whose turn is it to talk now?" (October 6, 2003, 1/2 block). One example demonstrates her expectation that students use other students as resources. On October 6, 2003, the problem of the day written on the board was "Brainstorm and record situations in which you may need to use estimation. Explain any estimation strategies that you would use for these situations." As the class started, the room was very quiet. Nancy reminded the students that they could share ideas with their table groups and record those ideas also.

Nancy identified the changes she made in her questioning techniques as one of the biggest changes she made in her teaching practices (May 16, 2002, Discourse in the Mathematics Classroom, Reflection #2). Previously, Nancy had used questions as a discipline tool to redirect students who were off task (May 16, 2002, Discourse in the Mathematics Classroom reflection #2). In watching Nancy's videos, I could only identify one example of this. In her November, 29, 2000 video tape she had the students make a scale drawing of a person. Before the students begin working on the activity, Nancy had the class discuss ways they might determine the appropriate lengths for the scale drawings. One student explained how to set up a proportion for a particular piece of the picture. When Nancy asked the student to explain why the numbers were placed in particular places in the proportion, the student stumbled through an explanation. Nancy asked other students for their thinking and several other students contributed to the discussion. In the video, one student appeared to be facing away from the main discussion. To this point in the video, Nancy had only called on students who volunteered to answer questions. This time, Nancy called on the distracted student, asking what the student thought about the answers provided so far. Nancy was using her question to pull the student back into an active engagement in the conversation. This is the only obvious video example of Nancy clearly using a question to deal with a potential discipline problem. However, because Nancy said she purposely used questions that way, her selection of volunteers may have been discipline driven also.

During my observations, many students were eager to participate. Because so many students were willing to participate, Nancy tended to ask volunteers to answer questions. The only time I noticed her calling on non-volunteers was within small groups, or when asking a student to share with the whole class an idea the student had shared in the small group. The classroom felt inviting, even in the early part of the year when I did my earliest observations. The students already seemed eager to share and discuss their thinking. When Nancy dealt with discipline issues, she did so by moving by the student, or by reminding the students of her expectations by verbally restating the expectation (see October 6, 2003 1/2 block observation previously discussed). The idea of using questions as a discipline tool appears to have become obsolete in Nancy’s classroom, which is the change Nancy wanted to accomplish.

As a result of changing her questioning practices, Nancy created another change in the classroom. One of the questioning techniques that she started to use was “not confirming answers as right or wrong, but allowing the students to give all the answers that they have found" (May 16, 2002, Discourse in the Mathematics Classroom, Reflection #2). This questioning technique was introduced to the program participants and modeled in the program. This technique was attractive to Nancy because she wanted to increase students' confidence in their mathematical ability and motivate more students to participate. Nancy wrote, "Students learn by this practice that math is a process—sometimes of trial and error and that it's all right not to understand some concepts at first" (Winter 2001, Journal 4). Asking for multiple answers and having the students discuss those answers served as a way to encourage more students to risk sharing their answers, increasing the number of students willing to participate. Nancy felt this was important because:

> Often times in math classes, students will wait for the "smart" student to answer, accept that answer as accurate, and never bother to question it. Even worse, many students have no idea of how the answer was arrived at and do not understand the concept, yet feel inferior if they ask a question. By using the type of mathematical discourse that requires many students to give their answers without the teacher verifying the answers as right or wrong, most students will stay with the discussion because they are eager to find out the correct answer. (May 2, 2002, Discourse in the Mathematics Classroom Reflection #1).

Nancy had stated her commitment to empowering more students in mathematics. She does this by creating an environment where thinking is important and the risks in sharing their thinking are reduced. By collecting a list of derived answers and discussing the processes used to arrive at those answers, Nancy reaffirms the students' abilities to reason mathematically.

Nancy's Shift in Mathematical Authority

As a result of changing her practices regarding the sharing and discussion of answers, Nancy has made a major change in her role as the classroom teacher; she has removed herself as the sole mathematical authority in the classroom and transitioned into role of facilitator. Her early videos provide evidence that Nancy operated as the authority, against whom mathematical correctness was to be judged. In my observations, Nancy had moved away from that position and had become the authority that facilitated and managed conversations, but correctness was now determined among the students. In some of Nancy's early video tapes, she only solicited additional answers when the first student had given an incorrect response. Otherwise, if the first answer offered proved to be correct, Nancy did not solicit other answers. For example, this conversation from the October 15, 2001 video of a lesson on rounding shows Nancy using Students 4 and 5 to make Student 3 aware of a mistake.

> Nancy: So let's take a sample problem and do what she was talking about. Let's use this problem to demonstrate the strategy. (she writes 738 on the board) Which place are we rounding to?
>
> Student 2: tens
>
> Nancy: Ok, we have ones, tens, hundreds (pointing to board). Student 3, which number is in the tens place?
>
> Student 3: Eight

Nancy: The eight? What do you say, Student 4?

Student 4: The three.

Nancy: Student 5?

Student 5: the three

Nancy: The three.

Student 3: I meant to say three.

Nancy: You meant the three OK. So the three is in the tens place. Student 2, go ahead a finish out rounding that off to the nearest ten….Finish the sample of what you gave us before.

Although Nancy did have many students give an answer, she was still giving clear signals about the correctness of the first response. These signals served to maintain Nancy's position of power as the sole mathematical authority.

Later in Nancy's videos she had a few examples of soliciting several answers and having the students discuss those answers. I also saw evidence of this during my observations, although not frequently. What I did see more evidence of during my observations was the students automatically offering an explanation for their answer and other students saying they agreed or disagreed. For example, in my November 11, 2003 observation of Nancy's 6/7 block, one student shared the answer to a multiple-choice problem of the day and immediately explained how that answer was determined. Nancy asked the class, "What do you think about what [the student] said?" Another student volunteered, "I disagree because…" and immediately provided an explanation. A third student volunteered and responded with, "I disagree with [the second student] because,…" and provided a different way of thinking about the problem. Nancy then called on the first student and asked, "What do you think about what [these two students] have said?" As the conversation continued, more students volunteered to share their thinking and eventually the second student said, "Oh, I want to change my mind now." When Nancy asked for a reason, the student explained that something one of the other students said had cleared up a misunderstanding. Nancy gave no indication about the correct answer in this discussion. The students arrived at an agreement on the answer themselves. Toward the end of the discussion, I heard several students expressing their agreement with the corrected answer. I observed many more of these kinds of discussions. Nancy operated more like a crossing guard, making sure the students crossed back and forth without hurt feelings, but she did not determine the direction. The students were free to cross in any direction, as long as they offered an explanation. Although Nancy did revert to the sole authority in one lesson I observed, generally she has positioned herself as a facilitator through her questioning. This is not a change that Nancy was aware of having made, and not a change that she sought to make. It has however, improved the quality of conversations in her classroom.

Nancy's Change in the Utilization of Journals

The next change that Nancy made in her practices involved the use of journals. As Nancy established norms for classroom discussions and began to plan her lessons around classroom discussions, she noticed that some students were not participating in those discussions. Nancy video taped a discovery lesson in which the students derived the formula for the area of a circle. In her written reflection of this lesson, Nancy noted that she was dissatisfied with the percentage of students who participated in the discussion about the formula. To fix this problem, Nancy stated that “next year I will ask students to write their thoughts in a journal entry before the discussion so that everyone has something to contribute and therefore may focus more intensely” (April 26, 2001, Video Reflection). Nancy’s comments indicate that she wanted to give some students more time to process their thinking and saw journals as a way to accomplish this. During my observations, Nancy’s use of this technique was evident. During one observation (October 6, 2003, 3/5block), Nancy began the class by having the students brainstorm situations when they would use estimations and what estimation strategy they would use in each situation. The students began working individually and wrote their ideas in their journal. After a few minutes of quiet, during which no one was talking, Nancy reminded the students that they could share ideas with their table groups. Much discussion ensued. Following the table group discussions, Nancy then pulled the class together to discuss possible situations. After the students left, Nancy explained to me that she used the individual writing to give students some time to think about the question, and then used the group as a place where students could validate their thinking. Nancy shared that her previous use of journals had mostly been for writing, but not in a way that offered processing time before discussions. I saw the new use of journals repeated on other observation days also.

Nancy’s Change in Hands-On Activities

As the discourse in her classroom improved, and as the program encouraged the continued exploration of the differences between constructivist learning and traditional views of learning, Nancy became dissatisfied with how she was using hands-on activities groups. Although Nancy had started using hands-on activities and groups long before she entering the program, she realized that the way she was implementing the ideas was not encouraging student thinking. Although Nancy made these two changes in connection with each other, they are indeed separate changes. Her concern was:

> When I did a hands on activity it would be a step, they would have a step-by-step directions. Maybe a lot of times it might have been from the book or something that I had come up with and they would just follow those directions and then I would kind of wait until they were done. I would maybe go around to check but just to make sure they were doing the steps. (October 30, 2003, Preobservation Interview).

The students usually did hands-on activities in groups, but Nancy noticed that the groups were only on task when she stopped to check on them, and quickly drifted off task when she moved away (March 15, 2001, Video Reflection). Nancy's experiences in the program had helped her discern that she was using activities as steps to follow instead of rich, mathematical explorations. Nancy took one of the activities back to her classroom, a discovery lesson on the relationship between the circumference and the diameter of a circle. After teaching the lesson, Nancy reflected how doing the activity in class had helped make her aware of all of the mathematical connections in the lesson (March 15, 2001, Video Reflection Course Content). Nancy became aware that constructivist lessons were not procedural activities leading students to a conclusion that could be made without any thinking on their part, which is what she had been doing.

During my observations, Nancy's classes worked on two different hands-on activities. Through these two activities, Nancy showed growth in her use of activities by allowing student to construct their own understanding during the activities. However, one of the activities was still constructed and managed in a very teacher directed fashion. The first activity utilized pattern blocks focusing on the difference between part-to-whole ratios and part-to-part ratios (November 10, 2003, 3/5 block).

The second activity was titled "The Amazing Cubed Candy Company" was a proportional reasoning activity. (November 11, 2003, 3/5 block) In the pattern block activity, Nancy gave the instructions verbally and the students worked in groups to identify all the comparisons between pieces. Individuals in groups suggested comparisons, and the groups discussed the comparisons. Those ideas were eventually shared with the whole class. Then Nancy asked the groups to find ways to use the pattern blocks to demonstrate whole-to-part thinking. Again, individuals in groups proposed ideas and the group discussed the idea. The ideas were then shared as a group. After these two segments, Nancy asked the students to explain the similarities and differences between part-to-part and whole-to-part ratios. This activity was constructivist in nature and helped students develop their conceptual understanding of ratios.

The goal of the "Amazing Cubed Candy Company" activity was to have students discover how to do proportions. The activity had the students count and record the number of each colored cube in their bag, determine the ratios comparing colors, and then use those ratios to determine how many of each color would be in four bags. One of the last questions on the handout asked, "Is there a mathematical way that will always work to find the number of Amazing Cubed candy in 4 bags? Show and explain your answer" The final question asked, "Can you determine the number of a certain color of Amazing Cubed Candy in any number of bags of candy or *n* bags of candy? Show or explain." In the discussion the following day, Nancy very much led the discussion toward the students listing equivalent fractions and using cross multiplication to find missing numbers in the proportions. These are procedures that would always work, but as I was observing I wrote in my field notes that the students seemed to be missing the conceptual understanding behind setting up the proportions. Nancy was leading them through this part of the activity and was not focusing on the proportions in a conceptual way. She was walking them through the procedure for cross multiplication without basing the procedure in any conceptual understanding.

These two activities, the pattern block activity and the "Amazing Cubed Candy Company" activity, demonstrate that Nancy has been made aware of the difference between leading students through to a mindless result and developing conceptual understanding. She was able to reconstruct pieces of the activities to be more conceptual than procedural. Unfortunately, the activities also show that Nancy was still reverting to leading the students through activities at times.

Nancy's Changes in the Utilization of Groups

Nancy has also learned to better utilize groups. In both of the previously described hands-on activities, Nancy gave the groups specific questions to discuss. Previously, Nancy had been describing the task and then turning the groups lose. She circulated around the room to make sure the groups were on task, but her questions to the groups tended to focus on whether or not they were following the steps and not on the students' thinking (October 30, 2003, Preobservation Interview). The change Nancy has made with groups is to ask better questions as she is circulating, questions that encourage students' to explain their reasoning. Before, she felt she was not focusing the group discussions on the concept the students were supposed to be learning (May 2, 2002, Discourse in the Mathematics Classroom, reflection #1). Now she asks questions like "what would happen if you…" and "why did she say that?" (November 11, 2003, 3/5 block), "Your tables look different. How are they really the same?" (October 6, 2003). Her focus during group time is now on having the students share their thinking and she is less concerned with whether or not they have accomplished each step of a task.

Nancy's Future Goals

Regarding future goals, Nancy said she is still struggling with balancing the time that discussions take with the number of objectives she has to cover in each nine-week period. She said that she needed to do a better job with this balance and learn "when to let them go and when to finally say hey, this is the correct answer" (October 30, 2003, Preobservation Interview). Coming to peace with herself when she has to end a discussion because of time is the next step in this process (October 30, 2003, Preobservation Interview).

As for additional changes or bigger changes that Nancy has planned for the future, she said she was going to take some time with her family, recovering from finishing her masters and getting the article about her research published. She felt she needed some time to relax (October 30, 2003, Preobservation Interview). When I asked her about the likely genesis for her next idea, she answered:

> I'm more likely to read research articles, to talk to people who are well versed in a certain thing and I'm more likely to seek it out and research it more formally than just making instinctive changes because it's opened up that world that there is this research out there and that's there's constantly good practices and things being made and those are going to benefit the way I deliver instruction (October 30, 2003, Preobservation Interview).

She intends to keep reading the journals and magazines she has been reading and was confident that another idea would spark her interest. However, this time she thought she would be better able to track that change in her classroom in a more formal way, rather than just instinctive implementation. She did not, however, offer any suggestions as to what the next change might be.

Summary of Nancy's Changes

Nancy's motivation for pursuing better discussions in her class come from her desire to have students enjoy mathematics, and see it as valuable to them. Nancy believed that, "Through the practice of mathematical discussion, many more students became engaged in the lessons. Many lower achieving students gained confidence and were willing to participate in discussions" (June/July 2002, Final Program Evaluation). Her discussions with Dr. Pape during the first course of the program and the course readings about discourse helped her identify student-centered discussion as fitting "my personal teaching style and my kids needs" (January 22, 2004, Final Interview). Nancy described finding out about classroom discourse this way:

> So many times in my teaching career I've had something where I've done something because it was an instinct to do it and then all of a sudden I'll read about it and say I do that. Now it has a name and now it has—it makes it a little bit to a higher level maybe and that's happened to me a lot. So I think that that's what it did is that it brought to a conscious level something that was real natural with me anyway and then it gave the research and the elaboration on how you actually make a class that does focus on that. And when I read those articles it just clicked with me and said this is how I could make my hands-on [activities] more meaningful (October 30, 2003, Preobservation Interview).

The important aspect of the change for Nancy was that "it clicked" with her. Why it clicked is vital in understanding Nancy's motivation. Nancy had written that she was a highly gifted verbal student who felt less capable in mathematics than in writing (Winter 2001, Focus Group). When she was a child in school, she thought that not understanding mathematics as easily as she understood other classes meant that she was bad at math. As an adult, she understands that she can do mathematics but that mathematics is just not as easy for her as are other topics (Winter 2001, Focus Group). Nancy indicated that because of the increased use of discourse in her classroom, students who were verbally gifted were able to achieve greater success than they would normally experience in a mathematics classroom. Nancy perceived that the increased amount of discussion in her classroom had addressed the learning style of some students, helping those students perform better in the class. The students increased performance was also increasing the students confidence, creating a synergistic energy.

In the preobservation interview (October 30, 2003), Nancy shared that she had a friend in high school who was good in math. Nancy and this friend would work on their math homework together by talking about the problems or concepts behind the problem. Nancy attributed her understanding of that content to these discussions. Having experienced this personally, Nancy transfers the need for discussion onto her students:

> The educational value that all children need to process mathematical concepts in a way that makes sense to them is accomplished through mathematical discussions. Through the use of mathematical discourse, students learn to work through problems in a way that makes sense to them. They can transfer this problem solving process to other classes and to their lives in general. Students have historically been fed mathematics in a teacher-directed format. Only those who processed information identically or similarly to the teacher gained mathematical understanding (Spring 2001, Journal 3).

Given her strong personal experience with success through discussion, her immediate attraction to this teaching practice becomes clear. Nancy wanted to recreate for her students the success she had experienced.

In summary, the overarching changes that Nancy made involve the use of discourse in her classroom. She made additional changes in her use of cooperative learning groups and hands-on activities as sources of stimulation for the discussions.

Nancy's changes all started early in the program, because Nancy entered the program with beliefs aligned with the reform-based philosophy.

Lorraine

During the program, Lorraine made changes to her homework practices, and she has continued to use those new practices. However, the major change in Lorraine's teaching practices is her willingness to try new things. During the program, Lorraine often discussed why things would not work in her classroom. Due to changes in the school schedule this year, Lorraine has been freed from some of those constraints, and has actually started to use some of the ideas from the program. One of the changes she has made is the arrangement of her room, putting her desks together in groups instead of rows. Additionally, Lorraine is beginning to include more discussion in her class, moving away from just reading the correct answers and doing all the telling herself. The increase of student discourse in her classroom reflects an emerging change in her beliefs about learning mathematics. She is interested in incorporating children's literature into her mathematics classroom, and has created some lessons and a project based on children's books. With the exception of using children's literature, the changes she is exploring are practices that were encouraged during the professional development program. Underlying all of these changes, or perhaps because of these changes, Lorraine seems to be shifting her thinking about what mathematics teaching looks like. Although she is not as far into this process as some of the other teachers in this study, she has changed some of her thinking.

Lorraine's Changes in Homework

The first change I want to examine was the focus of Lorraine's research project, changes to homework practices. At the beginning of the program, when other teachers were saying they wanted to improve the discussions in their classroom, or to shift the classroom from teacher focused to student focused, Lorraine had decided she wanted to focus on using her assessments better (Summer 2000, Bio). Throughout the program, she discussed various ideas related to assessment, such as using assessment to inform her teaching, and using rubrics to help her better understand student thinking (Summer 2000, Journal 1). Lorraine's focus eventually landed on her homework practices. Notice the disparity in the following journal response, between what Lorraine wanted homework to become and what she said she would research about her homework:

> Homework—getting students to complete it. Making it meaningful, finding a better way to grade to get homework back on time. It's important because homework is a big part of the class. I want to find a way to make homework meaningful so that they do it and try going over the solutions to help them on quizzes, tests, etc. This homework issue is a big part of the reform of my classroom. I need to find a way to grade it quicker and better ways to go over homework in a 40 minute period (Spring 2001, Journal 2).

At first, she talked about making homework more relevant to students. She then moved into the issue of time restrictions and focused on procedural issues not at all related to motivating students. Lorraine's research questions were "will the completion rate of homework increase if homework is graded and self-corrected daily?" and "will implementing a required notebook which must contain all notes and homework increase the completion rate of homework?" (Spring 2002, Reflection #1). Lorraine changed her homework practice from collecting homework papers to taking a few minutes at the beginning of class to quickly assign a completion grade for homework and then going over any questions (Spring 2002, Reflection #1). She also instituted the practice of having students keep a notebook containing all of their assignments, handouts, and notes (Spring 2002, Reflection #1). Both of these practices are still in place in her classes, although she no longer grades homework for completion every day.

For her research project, Lorraine analyzed homework grades and analyzed student interviews conducted by Lorraine's support person. The interviews explored the students' motivation for completing different types of homework (Spring 2002, Reflection #1). From this project, Lorraine concluded that for some students, grades were not a motivating factor. She also concluded that students often failed to complete assignments because they were frustrated by not knowing how to do the homework (Spring 2002, Reflective Essay #2). In response to this knowledge, Lorraine said she might implement a question box where students could anonymously submit questions, and that she would make the students more aware of the fact that middle school Algebra courses count as high school credit, influencing students' future academic records (Spring 2002, Reflective Essay #2).

Lorraine also found that students failed to complete homework involving word problems at a higher rate than other kinds of assignments. This finding, however, was the only analysis she did connected to the relevance of the homework for students. The remainder of her analysis focused on what the students did and did not do regarding homework, rather than on the reasons behind those actions. Considering the focus of the professional development program on student thinking and reform-minded ideas for building on students' prior knowledge, Lorraine's particular slant on studying homework indicates that she had missed the point of the program. Her research project did result in lasting changes that are still implemented in her classroom. She is still grading homework for completion and still requiring students to keep a notebook.

Lorraine's New Changes

The next set of changes Lorraine made occurred during the year I observed in her classroom, and are not widely evident in the data collected during the program. With the beginning of the 2003-2004 school year, Lorraine's issue of time in class was removed. The schedule for the eighth-graders in her building was modified. Lorraine, being the only eighth-grade math teacher, had previously seen every eighth-grade student daily for approximately 45-minutes. This year, the eighth grade math and science classes have been blocked together. On Mondays, Lorraine sees all the student in 45-minute periods. Tuesdays and Thursdays are slotted as A days, and Wednesdays and Fridays are slotted on B days. On these days, half the students come to her for two class periods instead of just one. On those days, the other half of the students go to their science class for two periods. For instance, on an A day, her first period class comes for their normal first period 45-mintue time block, and then they return during the third period time block. The students who are normally in Lorraine's third period mathematics class spend their first and third periods that day in science class. On B days, the students attend the other class for two periods. Some of the periods are non-consecutive, like the first and third period switch, with the students going to another class between the two math periods. Some of the blocks are consecutive periods, like Lorraine's fourth and fifth periods, where the students just stay in Lorraine's room two periods in a row. Although this schedule arrangement gives her the same total number of minutes with the students at the end of the year, Lorraine felt that this blocking system provided more time for student thinking:

> This is the first year that we did the blocks where we have more time to problem solve and share solutions because I felt like we'd start a problem but then the bell would ring and then when you come back the next day that's hard to do. Just coming back—sixth and eighth period are split by a period but they can pick right back up because they've left their stuff and everything's just right there and they can pick back up a lot easier. So I think we use our time a little more wisely and we can share a lot more (October 27, 2003, Preobservation Interview).

During the program, Lorraine commented several times that she was unable to implement standards-based practices because she had insufficient time with her students. I did not understand why this was such an issue for her until I started watching her video tapes. While watching the tapes, the segments seemed very short. I thought Lorraine had been taping only portions of each class. However, I finally realized that she was taping the entire class, the length of the period was really just that short, especially compared to watching other teachers in her building, whose classes ran for two periods.

Lorraine’s Shift in Thinking About Mathematics Teaching

The length of Lorraine’s class periods during the two years she was in the program were too short to complete many of the activities encouraged in the program. However, teachers from other schools with class periods almost as short seemed to be continuing activities over several days and not finding that to be a problem, so I began to suspect that the timing issue, although important, was not the sole factor influencing Lorraine’s decisions. During the program, the program director occasionally asked the participants to use some specific activity from the program in their own classrooms. The participants then reported on the experience as an assignment. Commenting on having tried some problems in one of her Algebra I classes, Lorraine said, “that class isn't even 40 minutes because it's the shorter period and it's Algebra I, and you've got to get through this Algebra I stuff too and that's not necessarily where we are” (Winter 2001, Focus Group). This comment demonstrates how Lorraine used time as an excuse, but it also exposes the reasons Lorraine was struggling to implement the ideas from the program. She viewed the algebra content and the standards-based ideas as two separate sets of content to be covered. She was not integrating the standards-based ideas into the algebra content. Other teachers were able to look at an activity abstractly and discern the principles behind the activity. This allowed those teachers to modify an activity so that the activity was appropriate and useful within their curricular constraints while sustaining the intent of the activity. Lorraine kept trying to take the actual activity back to her classroom without any modifications. She was not separating the activity from the instructional practices behind the activity.

Lorraine's early inability to integrate standards-based instructional practices with her content may be due to the way she understands mathematics. Comments that Lorraine made during my interviews with her indicate that she has a very procedural understanding of mathematics. Lorraine said, "I am very good at memorizing and so if a teacher said negative times a negative is a positive, that's what it is. And you don't need to tell me twice and you don't need to prove it" (October 27, 2003, Preobservation Interview). In that same interview, Lorraine said this about her college math experiences:

> And higher level math, I hated college. I needed somebody to sit and tell me—like I just wanted to see how the problems were done and then I'll just do them like that. I don't want to know why it was and there were people actually wanted to know why and talked about why and I didn't care.

In the final interview, during our discussion about how mathematics is organized, Lorraine made this comment about how she learned mathematics, "We never did hands-on. But I don't know if doing hands-on stuff would have made an impact on me because I didn't care. All I need is the rule" (January 22, 2004, Final Interview). These statements must be examined in light of the fact that Lorraine listed her "good math understanding and background" as one of her strengths as a teacher (Autumn 2000, Bio). Lorraine had found her procedural knowledge of mathematics to be sufficient and did not view the standards-based teaching methods discussed in the class as necessary to developing a strong mathematical understanding. Given the limited time she had with her students each day, her reluctance to integrate those ideas is easily understood.

Based on her belief that her memorized version of mathematics is a strong mathematical background, Lorraine seems to view students who memorize as strong math students also. Students who ask for or require connections to prior learning or conceptual development are viewed as less capable in some way. "…because I can memorize. I don't need to understand why. And there are kids who don't. You just tell them something once and they've got it" (January 22, 2004, Final Interview). About students who do not memorize and ask for more explanation, she said, "And other kids you have to break it down and show them all this stuff before they really understand" (January 22, 2004, Final Interview). This comment embodies the belief demonstrated in Lorraine's teaching practices that mathematics is procedural and can be memorized. This belief views mathematics as a set of steps. Good mathematicians understand those steps and can replicate and apply those steps without needing additional instruction, activities, or manipulatives. Lorraine said that explaining why things work is "…different from how I think" but that "helps me with the kids who don't memorize well, and don't feel that math is not just memorization" (October 27, 2003, Preobservation Interview). Lorraine obviously values a procedural approach to teaching mathematics over teaching for conceptual understanding.

Lorraine presented some conflicting thoughts about the nature of learning mathematics. The previous quotes indicated that Lorraine thought her knowledge of mathematics was sufficient and complete. When asked about looking at the *Principles and Standards* (NCTM, 2000) during the program and how that had influenced her thinking about the nature of mathematics, Lorraine said:

> I think that's what the standards are trying to tell us that math is not just plug and chug any more. It's really thinking and analyzing and problem solving. Not just the first step, this is the second step, this is the third (October 27, 2003, Interview).

Notice that in this statement, Lorraine did not say that she thinks this about mathematics. Rather, she gave someone else's vision of mathematics. Later in that conversation she referred to "the way we teach now," as if the new methods were just a different way to teach and not based on knowledge about mathematics and how students learn mathematics. This comment exemplifies a trend I noticed when comparing Lorraine's journal responses to her classroom practices. She often described what she knew to be correct practices even though she was not implementing these practices. At first, I thought this was a case of Lorraine just writing what she thought the program instructors wanted to hear. However, after observing in her classroom, I now think this might be Lorraine's way of "trying on" new ideas to get some idea of how they would impact her classroom (Senger, 1998-1999).

My supposition that she was trying on ideas is based on further comments made by Lorraine and on evidence from my observations. First, Lorraine's comments provided evidence that she was beginning to see her knowledge of mathematics as incomplete. When talking about higher-level mathematics classes, she commented, "at that point you can't memorize any more" (October 27, 2003, Preobservation Interview). She explained that she ran into some trouble with her content knowledge when she started teaching. Using integer multiplication as an example, she explained how she had memorized the rules for multiplication involving negative numbers; basically, she memorized rules for dealing with negatives. She stated that, “that rule worked for me until I was into teaching” (January 22, 2004, Final Interview). Because she had never really understood why the rules worked, she was stymied when her students struggled with the rules. She had limited conceptual knowledge, which prevented her from finding additional explanations for the students. In summarizing her position on the nature of mathematics and the role of memorization, Lorraine made this concluding statement:

> I think memorizing stuff works for—it worked for me but the problem is I really didn’t understand why things worked. So it’s great if you’re just trying to teach kids how to add fractions. These are the rules. This is what you do but as far as transferring it to any other things you can’t do that because you only know the steps (January 22, 2004, Final Interview).

Lorraine acknowledged that her knowledge of mathematics was limited, which indicates a change in her thinking about her own content knowledge. Remember, at the beginning she listed her strong mathematical background as strength, but she was now admitting that her background had weaknesses. Notice, however, how she talked about adding fractions. She indicates that teaching students to add fractions means teaching them the rules for adding. This signifies her belief that some mathematical content is understood at a procedural level. She is still missing the need to understand all aspects of mathematics on a conceptual level.

Lorraine's Changes in the Utilization of Groups

One of the biggest changes Lorraine made during the year of my observations was to arrange the desks in groups. Even though Lorraine had listed having her students work in functional groups as something she wanted to develop during the first summer of the program (Summer 2000, Bio). Some of Lorraine's videos show her students in traditional rows. In other videos, she has the students in pairs, two rows pushed next to each other with an aisle, and the next two rows pushed together with another aisle. Only one video evidenced students sitting in groups. Lorraine spent much at the beginning of that video sorting out which students were supposed to be together in groups. Once the students moved into their groups, she gave no instructions regarding her expectations for group work. The directions she did give sounded very similar to the typical instructions she gave when students were supposed to work alone. This video leads me to believe that Lorraine was unaware that productive and effective groups do not just happen; teachers have to establish expectations and teach students how to work in groups.

During my observations in her classroom, the first thing I noticed was that the room had been rearranged into groups. Lorraine said she was trying to use groups this year. She did not ever discuss having tried to establish norms for working in groups. Instead, she seemed to just expect the students to already know how to work in groups. The way Lorraine clarifies her expectations for group work is much more oblique than the direct discussions and explanations that Nancy gave. During my observation on October 1, 2003 in her 4/5 block, Lorraine assigned the group six problems to work through and discuss. She reminded students that they should show all their work and that groups should agree on the work, explanations, and answers the group submitted. However, she gave no specific reminders about how the students should talk to each other if they disagree or suggestions on how to help group members stay on task. As she talked to one dysfunctional group, Lorraine said to the group, “Why can’t we be doing math? Why is it so hard?” (Observation, October 1, 2003, 4/5 block). She did not offer any instructive comments, and immediately moved on to another group. Lorraine’s instructional practices are still very lecture oriented and she did not encourage the groups to discuss anything while she was giving notes. She used the groups after she had given notes, when the students were working on practice problems, or working on their homework. During activities, such as the activity where she had the students create templates for reflections across the x-axis or y-axis (Observation, November 11, 2003, period 4 of 4/5 block), Lorraine permitted the students to get help from each other, but she did not encourage them to work together. During an earlier observation, on October 1, 2003, in the 6/8 block, Lorraine asked the students if they should show work on their paper. The class responded with a resounding yes. Clearly she has made this expectation clear. However, all she said about her expectations for group work was, “If your group is not talking about math, it will reflect in your grade for this paper.” While Lorraine has started using groups in her classroom, she still seems unclear about how to establish expectations and norms for those groups.

When I asked Lorraine about the biggest changes she had made this year in her teaching, she quickly offered moving her room into groups. She went on to explain her motivation for using groups in her classes:

> So that when we do problem solving they can usually work together. There's a lot more conversation about math and just a lot more collaborating, working together. So it's not just me being the teacher telling everything. That they have a chance to work together. (October 27, 2003, Preobservation Interview)

Lorraine's lecture oriented practices are consistent with her procedural knowledge of mathematics. Given those teacher-centered practices, her desire to have more student discussion in the classroom appears inconsistent and perplexing. In reality, Lorraine's valuing of student discussions comes from her personal experiences as a mathematics student. Two different times during our first interview, Lorraine provided examples of how important mathematical discussion had been to her own personal understanding of the content. When she was describing her college level mathematics experience, she explained how she had not known any other students in her math classes. This left her without anyone with whom she could discuss homework problems. As she moved further along in her program she began to have classes with the same people, "then I knew people and then working problems was so much easier" (October 27, 2003, Preobservation Interview). Later during that same interview, she was talking about geometry proofs and how much easier they look to her now than when she was a student. Lorraine occasionally tutors high schools students in geometry. She noted that during these tutoring sessions, she can look at the proofs and recognize patterns in the proofs, making it easy to classify proofs into approaches. When I asked her why she thought that was easier to see now, she said, "Because I had to explain it to somebody else**"** (October 27, 2003, Preobservation Interview). In high school, as a student, she had a teacher that she thought was very good, and “that’s probably why I’m a math teacher now” (October 27, 2003, Preobservation Interview). However, he did not have the students discuss anything in class, the class being mostly lecture. Lorraine commented that those kinds of discussions would have helped her in high school and in her higher level college classes because, “once you start working with somebody else you’re talking and then you can see why” (October 27, 2003, Preobservation Interview). The fact that Lorraine has placed her students in groups, and occasionally asks them to explain ideas to each other, shows that she is beginning to shift her thinking about how active students need to be in creating their understanding. Slowly, Lorraine’s beliefs about teaching mathematics seem to be shifting.

Lorraine’s Incorporation of Literature

This year, Lorraine has implemented several ideas connected to using children’s literature in the classroom. Lorraine used the book *If You Hopped Like a Frog* (Schwartz, 1999) to create a project for her students connected to understanding proportional thinking conceptually. Lorraine also plans to use a book title *Spaghetti and Meatballs for All* (Burns,1997) to help students understand the relationship between perimeter and area. She has also used *Socrates and the Three Little Pigs* (Mori, 1986) with her Algebra students this year to teach permutations and combinations because “it really does a good job of explaining it” (October 27, 2003, Preobservation Interview).

Lorraine said that these ideas were motivated by a course that she and Nancy took the previous summer, which was not a part of the professional development program but which did count towards her masters degree. I found it interesting that all of these books take a conceptual approach to their respective topics. By reading and discussing these books, Lorraine is beginning to approach these topics conceptually. Even though she may still be focused on the procedures behind those topics, as she uses these books and has success with them in her classroom, perhaps she will increase her own understanding of mathematics and become more inclined toward standards-based teaching.

Lorraine's Future Changes

Lorraine did list future changes other than continuing to work on the ideas she has just recently implemented. For instance, she intends to continue the inclusion of children's literature in her classes and would like to find additional books that could be used in her eighth grade classes (January 22, 2004, Final Interview). She also plans to continue the use of group work. She is just beginning to experiment with several changes that are new to her and plans to make those changes a priority.

Summary of Lorraine's Changes

I have discussed motivating factors for each of the specific changes Lorraine made. There is one motivating factor that seems to permeate all of the changes Lorraine has made and continues to make. The influence and accountability of working with others played a big role in all of the changes Lorraine made. When she started the program, she said she was looking forward to working with her colleagues (Summer 2000, Bio). Later that first summer Lorraine wrote, "I need someone to evaluate me when I make some of my teaching changes and to keep me motivated to keep going when the changes seem overwhelming" (Summer 2000, Class Evaluation). Although she points here to the importance of encouragement, there is a tone of being held accountable in the beginning of the sentence. Early in the program, Lorraine fixated on changing her homework practices, even though this was not in line with the intent of the program. Through many discussions, the instructors in the program sought to push Lorraine in another direction. In one of the journals, Lorraine was asked to identify some additional goals, other than just working on homework. She wrote, "I guess I could say that I have expanded my goal to include not only getting different students to participate but also working on their answers—how well they explain and justify their answer" (Winter 2001, Journal 6). There is almost a grudging tone in this response, indicating that if it were not for the instructors trying to push her, she would not be thinking beyond having more students doing homework. In the final program evaluation (June/July, 2002), Lorraine wrote that she enjoyed working with the other teachers from her building and found their feedback valuable. From these, and other responses, I was starting to sense that Lorraine required accountability and the urging of others to enact changes in her classroom. In the final interview, Lorraine talked about how she could make the time to go observe other teachers or to formally reflect on her lessons, if she had to. She said:

> But that's how I think a lot of change is. While I was taking classes you think oh it's an assignment. I've got to try this; I've got to change, I've got to do something and you know somebody is going to be asking you about it later. It's so much harder to make a huge change in the class when it's just you and there's no . . . you don't do that unless you're forced to (January 22, 2004, Final Interview).

Having made the connection with the other teachers in her building, Lorraine felt some pressure to implement the change she thought the other teachers had already accomplished. This residual pressure, left over from the program, appears to be pushing Lorraine into finally making some of the changes promoted in the program.

Jonily

An analysis of the individual changes made by Jonily was difficult. Each change that she made seems to have resulted in further changes, with the line between the changes often blurring. The biggest overall change that Jonily made in the four-year time span from the start of the program to the end of this study was in the use of student thinking. From her early videos to the time of my observations, her classroom became one in which student discussion of mathematics drove the direction of the class. Jonily has learned to listen to what students say, to dissect what they say, and to provide experiences to clarify misconceptions or to build bridges when students demonstrate a lack of conceptual understanding. She uses discussions, questioning techniques, group work, writing tasks, and appropriate problems and assessments to support her efforts to understand and build on student thinking. Jonily recognizes many of those supporting practices as changes that she made in her teaching, but she did not list student thinking itself as a change. First, I will describe how her use of student thinking has changed, then how the supporting practices of group work, writing tasks, and appropriate problems and assessments have changed and contributed to the bigger change. Finally, I will explain additional changes she has made regarding homework and authority in the classroom.

Jonily's Use of Student Thinking

Jonily entered the program already having explored some of the philosophies and ideas connected to reform-based teaching, much like Nancy. Jonily explained that her experiences in the Master of Education program she attended exposed her to standards-based teaching (June 3, 2003, Pilot Study Interview). She explained that even though some of the other students in her M.Ed. program found standards-based ideas to be irrelevant, she kept an open mind and wanted to absorb all the ideas she could (June 3, 2003, Pilot Study Interview). Thus, she entered teaching open to using hands-on, inquiry methods (Summer 2000, Journal 4). Through the professional development program, she revisited many of the ideas from her M.Ed. experiences and, she said, "I learned how to implement it because I was then teaching at the time, so it made more sense to me" (June 3, 2003, Pilot Study Interview). Although Jonily was open to using those ideas, she explained that using traditional methods seemed more natural to her, natural meaning easier or more instinctive (Summer 2000, Journal 4). The incorporation of discussions was also instinctive to Jonily, and had already incorporated student discussions into her classroom before she entered the professional development program. The way she had been using discussion is described below:

> For example, if I was [*sic*] teaching doing an example on the board, the next example would be one that students would complete themselves. I would then ask many students what answer they got. I would write all of these answers on the board and the class would decide which answer was correct and why. We would also discuss how some of the students may have gotten incorrect answers.

> Of course I couldn't do this with every single problem because of the time it took but I wouldn't have wanted to. Doing this all the time would have gotten boring for the students (Summer 2000, Journal 4)

Jonily used discussion in her first year of teaching, but only as a way of sharing answers to problems. These discussions were teacher-directed, with Jonily asking all the questions, thereby guiding the direction of the discussions. As she progressed through the professional development program, her use of discussion broadened and changed.

Early in the program, Jonily was very much in charge of the direction of discussion in her classroom. In a video tape of a lesson from November 13, 2000, Jonily had students work on a project to find the best area for a garden with size specifications and cost constraints. As the students began to work on the project, Jonily began to worry that the students would not know how to get started, so she decided to walk them through an example (Autumn 2000, Reflection of Teaching). Prior to pulling the class back together, the students had been working in their groups and Jonily had a conversation with one particular group about the problem. When she decided to walk the entire class through an example, she asked one of the group members to share the example of the rectangular garden that the small group had discussed. When the student gave the dimensions, Jonily drew a rectangle on the board and wrote the given dimensions. Jonily started the conversation by observing that the given rectangle would not work for the project, and asked why. A student explained, and Jonily repeated the students' explanation and elaborated on it. Jonily then explained that they would go ahead and find out how much it would cost to put fencing around that same rectangle and started that discussion with “What should I do first?” A student suggested that they find the perimeter. Jonily asked, “How do I do that?” When another student explained, Jonily asked the class if the stated answer for the perimeter was correct. Instead of allowing students to respond, Jonily proceeded to explain why the answer was correct. The remainder of the discussion proceeded in this leading manner, with Jonily’s questions guiding the students’ thinking. The majority of questions asked during this lesson were procedural questions or questions that required only yes or no as the answer. This example shows that early in the program, Jonily was indeed using discussion in her classroom, but she was not yet allowing student thinking to drive those discussions.

Later during the first year of the program, Jonily noted that she was struggling with getting students to listen to each other during discussions. “When I talk, all eyes are on me, but when students start to talk or explain to the class, the rest of the students tune out” (Winter 2001, Journal 6). This is the first indication in the data that Jonily was starting to shift her focus towards student-to-student discussions in large group settings. As I will explain later, she was already using groups and having the students talk to each in small groups. But during large groups discussions, she was starting to desire a shift from teacher-student discussions.

When I first interviewed Jonily, she explained how she had witnessed another math teacher telling a student that there was only one way to do a problem. In our conversation about that event, Jonily began to talk about how important she thought listening to students is:

> And you've got to listen to the kids because—without having a true understanding of math, even if you listen to the kids and even if you hear them if you're not comfortable with—if you don't understand it you need to keep asking and say, "I don't understand what you mean. Can you tell me again? Can you tell me another way?" (June 3, 2003, Pilot Study Interview)

This quote demonstrates Jonily's belief that teachers have to provide instruction based on students' prior knowledge. To her, understanding a students' thinking is the first step in teachers being able to help students. During my observations, her use of student thinking to direct her lessons was apparent in almost every lesson. The following description of Jonily's use of a complex problem reflects the environment that she has created in all of her classes and demonstrates how she works to incorporate student thinking. This example comes from the September 4, 2003 observation during her first period class.

After finishing the warm up problems for the day, Jonily described a new problem the students would be working on over the next few days. This problem, one that was used in the program, involved the students taking on the role of a human resources personnel in a seasonal amusement park. In this role, the students were to use last year's data to select employees for rehire. After setting the stage for the problem, Jonily passed out the problem sheet, which included the details she had just covered and the data on which the decision should be made. She instructed the students to work individually to begin the data analysis.

As the students worked alone, Jonily circulated around the room answering questions and asking questions of the students. After they had spent some time working individually, Jonily pulled the class back together, saying that she wanted them to share the strategies they were using. She called on eight different volunteers, who shared their thoughts about how to look at the data, and different aspects of the data for consideration. As the students share their thoughts, Jonily asked questions such as, “Are you doing…?” or “When you said more important, why did you think it was?” The students clarified and Jonily did not restate or rephrase any of their answers. As the students shared, other students in the class also asked similar kinds of questions. Some students raised their hands and waited for Jonily to call on them before asking their questions of the student, but others asked without doing so. This discussion was very well mannered, and students seemed very comfortable with being questioned by multiple sources.

The last student who shared raised some issues about why the people in the problem might have worked more or less hours than others in the problem. A discussion ensued regarding the logistics of relating the amount of sales to the hours during which an employee worked, and the reasons that employees might be able to work only certain shifts. The students conducted the entire conversation. Jonily’s only role in this part of the discussion was to direct the traffic of the discussion, so that students who were raising their hand had a chance to participate

This kind of discussion tended to be the norm in all of Jonily’s classes. The questions she asked served to clarify a student’s thinking. Rarely did she ask a question that led a student to respond in a particular way. An additional example of this occurred during my observation on November 11, 2003 in her eighth period class. The students were trying to determine the correct answer for $-7-(-4)$. During the lesson, Jonily asked, “How did you get that answer?” Although this is a procedural question, she was trying to encourage the students to share how they were reasoning through this problem. Much of the class time was spent looking at different examples that students raised in trying to justify their answers to the original problem. Jonily ended the class without the class having reached a conclusion about the problem. After the students left the room, Jonily shared with me that the discussion had shown her that many of the students had not internalized an understanding of addition and subtraction with integers. She was very concerned about how she could work with the majority of the class without losing the interest of the few students who clearly understood the concepts. By the time I arrived to observe the next day, she had decided to differentiate the assignments for the day, providing some students with more concrete experiences with integers while others worked on an activity to extend their thinking in this area. When she first entered the program, Jonily would have led the students to a conclusion the previous day, and allowed herself to think that all the students had followed the explanation. Instead, she now habitually listens to students’ explanations, encourages them to debate and support each other, until there is clear evidence of consensus or divergence, at which point, she makes decisions regarding subsequent lessons.

When I asked Jonily about this transformation, and how she had learned to be more student-centered, she stated that the professional development program had made her more aware of the need to listen to students (June 3, 2003, Pilot Study Interview). Through the program’s emphasis on recognizing multiple ways of approaching and solving problems, she was made aware of the need to understand how individual students where thinking about problems. She also noted that starting with students' understanding and helping them build from their way of thinking helped avoid many of the "when are we ever going to have to use this again" questions and kept more students engaged in the lesson because their point of view was valued (June 3, 2003, Pilot Study Interview). Jonily thinks this kind of environment helps the students learn more because:

> The kids are doing more of the thinking and the doing and the solving and they're held accountable. They're not just an observer and they know that. When they come into my classroom they are going to do and they are going to work and they are going to think and I in my opinion the doing and the thinking helps them understand better and it really does help them learn better (October 23, 2003, Preobservation Interview)

Therefore, her motivation to begin the practice of building on students' thinking came from looking for multiple approaches to problems. The motivation to continue the practice came from evidence that the students were benefiting and finding this kind of interaction more rewarding. Jonily also finds these student-directed discussions rewarding because it constantly increases her knowledge about mathematics and ways to make the content more relevant to her students (October 23, 2003, Preobservation Interview).

Jonily's Changes Supporting Student Thinking

In her transformation into this student-centered classroom, Jonily made additional changes that supported her transformation. Changes in her questioning practices, use of groups, use of writing, and the inclusion of richer problems and assessments contributed to the change in how she negotiated student thinking. Along with asking questions that were less leading and more of an inquiry nature, as demonstrated above, Jonily also reduced her use of questions that had only yes or no answers or that had one clear correct answer. When I asked Jonily why she thought she had gotten better at running a student-directed classroom, she answered, “when I first started I didn’t know what questions to ask other than what did you get for an answer and how did you get that. It’s all about the questioning” (October 23, 2003, Preobservation Interview).

Jonily’s Changes in Questioning

At the beginning of the program, Jonily’s questions tended to be fairly focused on procedures and correct answers. Here is a list of questions that she recorded from one of her videos: Is there a relationship between height and arm span? Is it equal? What would that line look like? What type of graph is this? What type of relationship is there between height and arm span? What do you notice about the relationship for the whole class? What do you think a graph going upward to the right means? (April 26, 2001 Video Reflection). This list of questions contains several that can be answered yes or no, and several that have one correct answer. As they read articles in the professional development program, discussed the kinds of questions other teachers were asking, and saw good questioning modeled for them in the program, Jonily began to get ideas about words she could use to improve her questions (October 23, 2003, Preobservation Interview). She also pointed out that she asked different students different kinds of questions sometimes, to build students’ confidence (January 14, 2004, Final Interview).

In each of her video reflections, Jonily commented that she had student engagement as a goal for the lesson. As a by product of trying to get more students involved in the lesson, Jonily realized that she was going to have to ask better questions (Spring 2002, Reflection #2). The kinds of questions she was asking at the beginning of the program did not facilitate discussions, and limited the number of students who could participate. At the beginning of the program, Jonily generally asked questions that had one fairly obvious correct answer. As she progressed through the program, she began to ask questions that had students comparing their work, analyzing other students' arguments, and that involved other higher order activities. This kind of questioning met her desire to engage more students.

Jonily's Changes in the Utilization of Groups

Also, because she wanted to engage more students, Jonily began to utilize groups differently in her classroom. In her reflection about the video made on November 13, 2000, Jonily wrote that she felt the need to discuss an example of how to analyze the cost of one specific arrangement of fencing. She wrote, "I should have just let the students discuss with their groups, but I was afraid they wouldn't know where to begin." She did not put students into their groups until after she had explained, with some student input, how to do the problem. In another video reflection, (Winter 2001, Video Reflection), Jonily commented that while teaching the lesson, she was bothered by asking questions and not getting any student response. She was concerned, after watching the video, that there were only 7 out of 20 students who participated in the discussion. Considering her goal to have more students engaged in the lesson, she suggested a change that she might try in the future:

> I think that if I ask a question and don't get a response right away, instead of waiting then asking a couple of other students, I could stop the class discussion and break into small groups for a short time. At this time all students have to think, and not just a few who are motivated to do so during a class discussion. I think that this would motivate students. Instead of being one of twenty students trying to figure out the answer, each student would be one of four students figuring it out (Winter 2001, Video Reflection).

During my observation, Jonily frequently had students share ideas with other student in formal and informal groups, but this group work never lasted for the entire period.

Apparently at some point between the first year of the program and the time I began my observations, Jonily felt that she had overused group work. After I had spent a few days in her classroom, Jonily commented that one of her goals for the year was to be more specific about group work and to limit the time students spent in their groups during any given period. She felt that students tended to drift off task in groups if they were in them for the entire period. In my observations in her class, I noticed a pattern of having students work or write individually, then moving them into their groups for a portion of the period. After having the groups share their initial thoughts and make some progress with a group decision, she would then pull the class back together as a whole so the groups could share with other groups. In many activities, like the Summer Job Problem, Jonily would give the students additional group time the next day. She seemed comfortable with this balance, and the students appeared to be engaged through most of the lessons during my observations. The only times that I noticed the student not engaged were on occasions when she had them working individually for the remainder of the period after doing the warm-up problems. In those situations, some student drifted off task and had to be reminded to get back to work. Jonily's change in the amount of time spent in groups was also motivated by the same goal. She thought that students were drifting off task when they were in their groups for too long a period.

Jonily's Focus on Writing in the Mathematics Classroom

Jonily identified writing as another major area of change in her teaching practices. At the end of the first year of the program, Jonily identified writing as her future area of focus (Spring 2001, Journal 3). In the journal response, she explained that students would have to provide written explanations on the Ohio Graduation Test and commented that they had a difficult time explaining their thinking in writing. Thus, she wanted to provide them with more practice to make them more comfortable. She also wrote, "I believe that "talking" and "writing" math will help students do math and understand math" (Spring 2001, Journal 3). This is consistent with her previously mentioned belief that students need to do math to become good at math.

In her classroom, writing has been included as a precursor to discussions. She often had students work alone and write down their initial thoughts before sharing ideas in groups or with the entire class. To facilitate their written responses, Jonily has incorporated a writing process titled "ODEAR," which stands for:

> Organize the information, Define the unknowns (what is the question asking?), Explore strategies (use these problem-solving strategies to work through and explain solutions to the problem), Answer the question(s), Reflect (Does your answer make sense? Why or why not?) (Spring 2002, Reflection #1).

This problem-solving strategy was created by a team of teachers, including Jonily, and the use of this strategy became Jonily's research project for the program. Jonily's research question was "How does writing in mathematics affect student attitudes, achievement, and conceptual understanding?" (Spring 2002, Reflection #1). During my observations in her classroom, Jonily made references to ODEAR on several occasions, but only at times when students seemed to be struggling with a problem. The students were familiar with the strategy, indicating that time had been spent familiarizing them with the use of ODEAR. I did not observe any instruction directly related to the use of ODEAR.

Jonily values students having a conceptual understanding of topics, and goes to great efforts to have them explain their thinking and support their answers, as described in the earlier section about student thinking. This writing process is an additional method she uses to encourage students to reason through and explain their thinking about mathematical situations. Although I did not see a vast amount of evidence demonstrating the use of ODEAR, she did have students write some kind of response in every class. Whether students were writing their thoughts about the warm-up problems, or organizing their thinking on a new activity, they used writing as a starting and ending point, with discussions supporting the development of their thinking.

Jonily's Search for Mathematically Rich Problems

Another change related to student thinking is Jonily's search for bigger, more encompassing problems. Jonily has started to organize her year into units rather than chapters. These units represent the conceptual way Jonily is trying to have the students look at mathematics conceptually, seeing as many connections between topics as possible. These units encompass many topics. So far, she has developed a unit on data analysis, one on patterns, one on linear relations, and one on rates. These units encompass many big concepts, and Jonily ties in skills whenever the skills fit within the different units, often revisiting required curricular ideas in several units (June 3, 2003, Pilot Study Interview). Although the idea of organizing the mathematics into units is not new to her, (January 14, 2004, Final Interview), what is new is the idea of using problems that are rich in mathematical content. Some of the problems she has collected came from the program. This year, she has gathered more problems from a course she is taking titled "Balanced Assessment." In her collection of rich problems are problems based on real-world examples, and others base on mathematical explorations. For example, with her Pre-Algebra classes on November 6, 2003, she used the following situation:

> Wheels-R-Us car rental comply charges $120 for a weekly car rental plus 15 cents for each mile driven. How much will the car cost if you travel 20 miles? How much will the car cost if you travel 50 miles? If you have $145 to spend on a weekly rental, how many miles can you travel? Draw a graph to show the cost of a weekly car rental. Write a formula to show the cost of a weekly car rental.

This problem encompasses arithmetic skills, graphing and data analysis topics, and algebraic and patterning concepts. In one problem, she was able to explore many different concepts. The Summer Job problem, previously discussed, is also another example of a real-world application. These real-world problems are important to Jonily because, “I think the most important thing that will show students the importance of math is to provide real-world examples and activities” (Winter 2001, Journal 4). She is convinced that through these kinds of problems, students will be better engaged in the mathematics and will find the concepts more relevant to their life.

Jonily also employs problems that are less situated in real-life contexts, but that are still mathematically rich. These kinds of problems tend to include patterning problems, and numerical explorations. One such example is the problem she used to generate a discussion about perfect squares, square roots, and non-linear data. Jonily presented the students the pattern 1, 4, 9, 16, . . . and asked them to tell her about the pattern. The first year she used this problem, she was surprised that the students examined the pattern in a recursive manner. She had not considered looking at the pattern in a recursive way (January 14, 2004, Final Interview). This led her to modify her patterning unit to include recursive formulas in the unit for the second year. Every year she uses the problem she becomes aware of more connections to other topics. Each year, she said, she has been amazed at the mathematical discussions that resulted from the exploration of this problem (January 14, 2004, Final Interview).

Although she has been pleased with the incorporation of bigger, more encompassing problems, Jonily is frustrated by the difficulty of locating additional problems. She decided to participate in the Balanced Assessment class because of the course's focus on the use of problems to assess student learning (January 14, 2004, Final Interview). Her hope is that her participation in the class will help her gather additional problems and ideas about how to use those problems.

Jonily was motivated to use richer problems in her classroom through her exposure to these kinds of problems during the program (June 3, 2003, Pilot Study Interview). The way these problems were used to bring out many mathematical topics and to stress the connections between those ideas was aligned with her emerging implementation of standards-based teaching. She quickly latched onto this practice, and has been diligently searching for additional problems.

Jonily's Changes in Homework Practices

Jonily has also made changes in her thinking about the use of homework in mathematics classrooms. In Jonily's own words:

> As a math teacher I guess I just figured you were to give homework every night and so I did. They had something to do every night. So when I first started teaching I would give 15-20 problems and then as I'm thinking about—okay, this is very traditional. I want to move away from this. As my second and third year of teaching came, I said you know what, I'm only going to give three, or four problems, but maybe they were still the skill problems. But, I didn't realize that at that time. So then maybe my third or fourth year of teaching I said wait a minute, I'm only giving three, or four problems a night but they're still skill problems. So then like last year and a little bit the year before I tried to give one

> problem but I had it a problem solving kind of thing. Then I started realizing—well they can't do all this in one day. So then I said now I'm going to give one problem, we're going to work on this for three days. And we started learning a lot more mathematics by doing one problem for three days than 35 problems in three days (January 14, 2004, Final Interview)

Jonily started with a traditional view of doing skill practice for homework. She has evolved into using richer problems that actually cover more mathematics at one time. Later during the same interview, Jonily explained that she is still struggling with this idea, because at times she still thinks the students need more skill practice. This year, she has taken the position that she will only give homework if she needs them to do something at home. This work might be skills practice or it might be spending more time exploring a bigger problem. However, she is only having students spend the time on problems at home if she needs them to do that for the next day. She is still trying to balance some of her traditional beliefs with what she thinks is best for the students. This struggle reflects a change in her beliefs about teaching mathematics. This change in her thinking was motivated by other changes she made, such as focusing more on students' thinking and using richer problems. However, because of her emerging practices in those areas, her thinking on homework is still in transition. In the final interview, she pointed to the Balanced Assessment Class as a way to help her further refine her thinking about homework.

Jonily's Shift in Mathematical Authority

The final change I will discuss in Jonily's teaching practices is one that was an unconscious change for Jonily, but aligned with her standards-based practices. Because of her increased emphasis on student-to-student discussions, and the change in her questioning practices, Jonily has shifted the power base of knowledge in her classroom from solely herself to include students and other resources. Jonily explained that when she first started teaching, if students struggled with a concept, she thought she needed to explain the concept again, indicating that the responsibility for explaining content was completely hers (October 23, 2003, Preobservation Interview). When she first started trying to have students explain their thinking, she had a habit of allowing a student to explain their thoughts which she would then restate in her own words. In the November 13, 2000 video of the lesson on analyzing the best dimensions of a rectangular garden given specific constraints, discussed in a previous section, Jonily conducted a discussion about how to analyze the costs. Throughout this discussion, she asked students to explain their thinking. Each time a student offered an explanation, she made sure the entire class could hear the student. Unfortunately, after the student finished explaining, Jonily restated and elaborated on what the student had said. This practice devalued what students had to say and placed importance on listening to the teacher. The frequency of this practice decreased somewhat in later videos, but was sill evident. During my observations, Jonily carefully facilitated conversations and did not restate students' thinking. She did frequently ask for clarification, but she did not ever assume to speak for the student. In Jonily's classes now, students hold discussions between themselves in which Jonily only participates as another spectator, especially in her Algebra class. Because she has had most of those students for two years in a row, they are very adept at discussing their thinking. Even her Pre-Algebra classes, with whom she had only been working for three months, were sharing their thoughts and asking each other for further clarification. The following brief transcript exemplifies the kind of conversations Jonily conducted with her Pre-Algebra students. This discussion took place as the class was going over the second warm-up problem on September 4, 2003, during the third period class.

Jonily: What did you get for the second problem?

Student 1: Six minutes.

Jonily: Anything different?

No responses

Jonily: We all agree again?

Student 2: Student 1, How did you get six minutes?

Student 1: (explains)

Jonily: Student 3, what do you think?

Student 3: (explains)

Jonily: Both had good explanations.

[Jonily then transitions into the next activity.]

With these students, Jonily was still prompting them to respond. Notice, however, that Student 2 asked Student 1 directly for an explanation without going through Jonily. In only three months, she had already established an environment where explanations from other students were as valuable as were the explanations provided by the teacher. This kind of discussion abounded in Jonily's classroom.

Jonily also encourages the use of other resources as authorities in the classroom. While observing on September 5, 2003, Jonily was working in her Pre-Algebra classes on mean, median, and mode. She began the discussion by asking the students what they knew about ways to analyze data, like test grades. One student offered finding the average. Another student suggested finding the mean. As soon as that student said mean, several others simultaneously said median. After some random additions, another student added mode to the list. Jonily then asked the students what they knew about the terms on the list. As a class, the students generated definitions of mean, median, and mode but some disagreement surfaced about which definition went with median and which went with mode. Jonily asked the class how they could figure out the correct arrangement. One student suggested they could look it up in a dictionary or math book. Jonily pulled a dictionary and a math book out of the cabinet and asked if someone would like to look up the terms. She handed the books to the volunteers, who proceeded to look up and read the definitions to the class. Jonily did not straighten out the students thinking as they offered definitions and she quickly agreed to using a source other than herself as a way to clarify the confusion. In this, she modeled how students could work through their confusion and demonstrated that mathematics is not always quick and neat. Before participating in the professional development program, this interaction would likely have resulted in her correcting the students' definitions when the students stated them. This example shows how Jonily has broadened the view of mathematical authority, decreasing the focus on the teacher.

Although Jonily did not list the shifting of authority in her classroom as a change, the video tapes from the program provide evidence that she was not always as much of a facilitator as she is now. While this change may be an unconscious one, it is consistent with the other changes she made and appears to be a result of those changes.

Jonily's Future Changes

When I asked Jonily about future changes she planned to implement, she indicated that she intended to continue developing units, increasing the number of units she has that are fully developed. She also plans to continue searching for additional mathematically rich problems. She talked about her growing dissatisfaction with the unit tests she has given. Those tests tended to focus only on the skills covered during the unit and not on the concepts, as covered in the rich problems she uses in the unit. She cited a dearth of problems and lack of time to develop rubrics to grade those problems as the reasons for her tests being skill-based. She is still struggling with these ideas, and feels like she often opts out of doing what she knows she should do because she does not have enough time, or she makes other choices with her time (January 14, 2004, Final Interview).

In addition to creating more units and improving her assessment tools, she also commented on the many different projects in which teachers in her building and district were involved. She explained that she tries

> to keep involved in what everybody else is doing because that way I stay on top of everything else that's going on around me and I just try to bring my own ideas into each of those things and so I just—because I want to work with my colleagues (June 3, 2003, Pilot Study Interview)

This involvement is not intended as a control issue or in a nosy way. Instead, she wants to continue to grow, and thinks all the ideas need to be pulled together in some way to give the school a coherent focus. By becoming involved in several different opportunities, she hopes to continue learning and bringing ideas into her classroom.

Summary of Jonily's Changes

Jonily has gone from using mostly traditional methods where the teacher tells students information, to having the students share their thinking as they discuss ideas and provide mathematical justifications for their arguments. This transition has also resulted in Jonily removing herself from the role of sole mathematical authority and has encouraged the students to see themselves as sources of mathematical information. She has increased the amount of student participation by having students share ideas in their groups, and by incorporating better mathematical problems into the classroom. By organizing her curriculum into units, she has helped her students experience mathematics as connected pieces, and has increased her own conceptual understanding in the process.

Conclusions

Summarizing the changes the teachers made, we see that the teachers made changes in classroom discourse, changes in the utilization of groups, and changes in the kinds of activities in which the students are involved. Nicole's focus on changing conversations in her classroom eventually led to an examination of her questioning practices and the impact these have on the classroom. Lorraine began to explore and discuss changes in classroom discourse. Nancy and Jonily both embraced classroom discourse, allowing it to impact other aspects of their teaching. As with discourse, all four teachers made different kinds of changes regarding the use of groups. Nancy, Jonily, and Nicole all made changes in their use of cooperative groups as part of their desire to change classroom conversations, although each had a slightly different goal for making changes in group work. While the other three made changes in the use of groups as part of another goal, Lorraine's changes in group work was a goal in itself. The category of changes in activities encompassed many ideas different ideas. For Jonily, she became interested in mathematically rich problems. For Nicole, the changes she made regarding activities involved gathering additional ideas to support the topics in her curriculum. Nancy's changes in activities centered on how she implemented the activities; she maintained her focus on improving discourse and wanted her implementation of activities to encourage better discussions. Lorraine, as with her changes in the use of groups, was just beginning to use new kinds of activities in her classroom during the year I observed. She was expanding her ideas about how activities could be used and the ways she wanted to incorporate those ideas into her classroom. On the surface, the teachers made many of the same changes. With a closer look, we see that the teachers really made varying degrees of changes motivated by different goals and desires.

Conclusions Consistent With Existing Literature

Although Nicole, Nancy, and Lorraine all teach in the same building and have similar teaching experiences, they all experienced the professional development program very differently. The teachers entered the program with different dispositions toward change, beliefs about mathematics, and experiences with reform-based methods. As we know with student learning, the learners' previous experiences and prior knowledge impact how they connect with new information (NRC, 2000). Theses teachers confirm that the same is true for teachers trying to learn new ways of teaching.

In my previous review of research about reform-minded professional development programs, I pointed out that the teachers in those studies made changes connected to the goals of the specific programs. This study also exemplifies that trend. All of the teachers in this study made changes emphasized in the program. All four of the teachers in this study talked about changes in the discussions in their classrooms, which is not at all surprising given the amount of time that was spent on this topic during each quarter of the program. Group work and better questioning were also common themes among the changes and program goals. Although the program had a heavier emphasis on discourse than on some other topics, the program covered a wide range of topics related to reform-based teaching. Consequently, all of the changes demonstrated by the teachers are, in some ways, connected to the goals of the program. Therefore, this study is consistent with the existing research literature.

Few studies have followed teachers' progress after their involvement in reform-minded professional development programs. In Franke, et al. (2001), case studies of two teachers were presented to examine the nature of the sustained changes two years after the program's completion. As in Franke, et al., all of the teachers in this study sustained some of the changes they had made during the program. In the current study, Jonily provides an example similar to Ms. Sullivan in the Franke, et al. study. Jonily has made changes that could be classified as generative change, as defined by Franke, et al (2001). She continues to use her changing understanding of mathematics to refine her units and to create new units, even discussing the possibility that she might have to rethink her exiting units. Having spent time focused in class on using discussions and better problems to build conceptual understanding, she is now questioning her use of assessments and provided evidence that this aspect of her teaching would undergo changes in the future.

Nancy is very similar to the example personified by Ms. Carroll (Franke, et al., 2001). Nancy made changes in line with those offered in the program, but has not yet gone beyond those changes. However, Nicole is more like Ms. Carroll than is Nancy in her thinking about learning. While Nancy has not yet made additional changes, she does not view knowledge as a fixed set of information. Nicole, on the other hand, does seem to be more similar to Ms. Carroll in that manner.

Lorraine provides an example that was not presented in the Franke, et al. study. During the program, Lorraine failed to make many of the changes that the other participants implemented. While she talked about those changes, the evidence of their implementation was very limited. It was not until the second year after the program ended and the time constraint on her classes was lifted that Lorraine began to use more student-directed discussions and group work. This is clearly not a case of self-generated change. Rather, this is more of an example of someone who buffers information for use at a later time. This manner of dealing with change is a new example that has not previously appeared in the research literature.

Also consistent with existing research literature, this study demonstrates that a teacher’s mathematical content knowledge and existing beliefs impact the teacher’s ability to make changes in her teaching practices. Although Nicole is growing in her understanding of standards-based teaching, as detailed earlier, she still behaves in ways that suggest her beliefs about teaching mathematics are in conflict with reform-minded approaches. Instead of examining the teaching behaviors and student behaviors necessary for making these activities successful, she is still identifying the activity itself as the change she needs to make. Through the program, Nicole started to change this habit. She did begin to look at improving the discussion in her classroom, which was a necessary component if her hands-on activities were going to be successful. However, her efforts to improve the discussions in her classroom show that she was still focused on activities that could help her do that. She struggled with discussions in her classroom and focused on asking better questions to improve those discussions. Math Court attracted her attention because it sounded like an action she could take toward having the students provide better explanations and justifications. However, I suspect that unless Nicole begins to focus on how she establishes expectations in her classroom, and what expectations she establishes, her efforts at implementing Math Court will not provide the results she is seeking.

The changes Nicole made during the program and her comments about those changes reflect deeper held beliefs and limitations that she had not yet addressed. Her procedural understanding of mathematics and her focus on completing lessons as planned indicate that she views mathematics as a neat, structurally rigid, and procedural organization of ideas. Using Thompson, Phillipp, Thompson, and Boyd's (1994) classifications of mathematical content knowledge, Nicole's content knowledge would be classified as calculational. Calculational knowledge is focused on procedures aimed at obtaining the correct answer. In this orientation, procedures are not always connected within the framework of bigger concepts. This view of mathematics will limit the way she can implement Math Court. For example, her content knowledge being very procedural is limiting the connections she can make within mathematics and causes her to miss connections she might make between curricular areas. This is going to limit her ability to help students improve their justifications in Math Court.

Nicole will also struggle with implementing Math Court because of her beliefs about teaching mathematics. Price and Ball's (1997) description of how non-reform minded beliefs limit the ways teachers implement reform-minded curriculum materials makes me wonder how Nicole's beliefs will interfere with the underlying philosophies of Math Court. If Nicole holds onto her belief that mathematics teaching is neat and orderly, and continues to value her commitment to completing her lesson plans, much of the intent of Math Court will be neglected. The possibility that students might offer a justification or an argument that diverges from what Nicole expected will not fit in with Nicole's beliefs about the orderliness of teaching mathematics.

While Nicole did evidence growth during the program, she did not show a great inclination for self-examination of her beliefs and values. I think that this lack of change in her beliefs will cause her efforts with Math Court to take much the same route that her efforts with discussions have taken. She will eventually arrive at an explanation for why the change is not working, as she did when she said teachers could not always ask higher level questions. Nicole is growing as a teacher, but her limited awareness of how her beliefs, values, and knowledge conflict with the changes she wants to implement are impacting further development toward reform practices. Teachers need to examine the impact their beliefs and prior experiences are having on teaching practices before they can overcome conflicting beliefs (Franke, Fennema, and Carpenter, 1997). As of yet, Nicole is not aware that she holds conflicting beliefs and has not yet taken steps to examine those beliefs.

Conclusions Not in Existing Literature

This professional development program was based on best practices designed to help teacher move toward reform-based teaching. While these programs do help teachers change their practices, this study indicates that such programs do not help teachers change the ways they approach making those changes. For example, Nicole and Jonily are still examining their classroom and selecting subsequent changes in the same way they were before they entered the program. Nicole listed Math Court as an activity she wanted to try in the future. Even after her extensive, long-term exposure to examining and changing one's teaching practices, she is still approaching change in her classroom by identifying activities that she wants to use in her classroom. She lists activities that she wants to use, but does not actively indicate an awareness of the necessary changes she would have to make to guarantee the successful implementation of those activities.

Remember, when Nicole first entered the program, she stated that she wanted to find more hands-on activities to use to teach her content. In her mind, "better activities" is synonymous with reformed teaching.

Jonily, on the other hand, makes changes after much internal dialog about why she does what she does in the classroom. When asked about future changes she wanted to make, Jonily stated that she wanted to improve her assessments. She was struggling with trying to balance the need to assess students skills in a way the mirrored her desired emphasis on conceptual understanding. Although the topic is new, this is the same process she went through when she entered the program. At the start of the program, Jonily was trying to reconcile her natural comfort with lecturing and giving notes with the ideas she had studied in her M. Ed. program. Jonily has developed the habit of examining her practices and beliefs about teaching in comparison to new ideas presented to her before she even started the professional development program.

Many of the informal discussions I had with Jonily, before and after classes, involved her thinking aloud about how what she had done did not match what she thought she should be doing. This often puts her in a self-reflective analysis, during which she tries on ideas to understand the impact on her classroom. Her way of analyzing the value of new ways of thinking is to try them in her classroom and to monitor student reactions. For example, when teachers in the program started exploring student-centered discussions, Jonily tried that in her classroom. She used student responses as an indicator of whether or not discussions were worth pursuing. Through these discussions, she discovered misconceptions the students had about the mathematics. Because her goal was to help students understand the mathematics, student-centered discussions provided information to help her with her goal. Therefore, she decided student-centered discussions were more valuable than lecture-oriented lessons, and began to shift her practices. Lorraine's efforts at change are very similar to Nicole's in that she holds beliefs that conflict with reform-minded practices. Nancy, on the other hand, is more similar to Jonily in her ability to reflect on why she behaves in certain ways. Because the discussion would be very similar to the comparison between Nicole and Jonily, I have decided not to include it.

Jonily's internal dialog about her teaching is very different from Nicole's. Jonily is much more adept at reflective assessment of her beliefs and practices than is Nicole. Nancy is very similar to Jonily, while Lorraine is similar to Nicole. Unfortunately, none of these teachers made any modifications in how they approach the process of change. All four teachers are still using the same methods for approaching change that they were using when they entered the program. These teachers did not have the kinds of experiences they required to change their habits of approaching change.

This study emphasizes the dichotomy between teachers who can self-evaluate their beliefs and those who do not and provides evidence that reform-minded professional development does not teach teachers how to self-evaluate their beliefs. Although all of the teachers in the program were asked to reflect on their efforts to implement change, Nicole and Lorraine tended to focus on their behaviors and actions and did very little examination of the motivating factors behind those actions. Jonily and Nancy explored the underlying reasons for their behaviors and were able to bring their classrooms closer to a pure reform model than the other two. The explicit awareness and examination of beliefs is important in helping teachers change their teaching practices (Ball, 1996 ; Borko & Putnam, 1995; Price & Ball, 1997; Franke, Fennema, and Carpenter, 1997). Some teachers, such as Nancy and Jonily, are more inclined to do this on their own. Teachers such as Nicole and Lorraine require different kinds of experiences to help them do this. The professional development program did not change the habits connected to examining and becoming aware of existing beliefs.

A comparison between how Nancy and Lorraine were motivated to make changes illustrates the difference between teachers who are internally motivated to change and teachers that require external motivation to create change. Nancy entered the program already aware of many reform teaching practices and had used many of them in her classroom. She stated that these ideas had come from workshops, and reading journals and magazines. Although Nancy never directly said this, the way she described getting these ideas implied that she seeks background knowledge about those ideas. Nancy said:

> I like to research the current thing, effective methods. I love it when I go to workshops and they have—like Columbus math department is real good about giving new ideas, new hands on things, new activities and I love trying those new things. (October 30, 2003, Preobservation Interview).

Nancy's first comment was that she likes "to research the current thing." This is very different from just being handed activities and worksheets that can be taken directly back to the classroom with little thought. When Nancy does gather new hands-on activities, she appears to have some background knowledge about the activity, which she has gathered through her reading. Nancy stays informed through her reading and does not take activities back into her classroom out of context. By that, I mean that as Nancy tries to implement new ideas, she also tries to understand how those ideas are situated in theoretically or philosophically. Through readings and workshops, Nancy keeps herself current on developments in teaching. Although this kind of research is much less formal than the research she did for the program's project, Nancy uses this informal research to stay informed about teaching theories. When asked about future changes she would make, Nancy suggested that those changes would come out of reading journals and magazines.

Lorraine, on the other hand, is more motivated to make changes based on what I will call peer pressure than she would by using reading material. Lorraine stated at one point that she was not interested in theory (Summer 2000, Class Evaluation). In all of our conversations, she never mentioned reading any teaching journals or magazines unless it was directly related to a class. She does use the Internet as a source of information, but all references to using the Internet were related to finding lesson materials for an idea that she already had, not for finding new ideas about teaching. Most of the changes Lorraine has made were the result of someone else's expectations for what she should be doing in her classroom. During the professional development program, the evidence indicates Lorraine only tried things because they were assigned. This year, she implemented some activities connected to children's literature, which was a direct outcome of the ESL course she had taken over the summer. In one conversation we had between classes, Lorraine was talking about a dysfunctional group that she had reprimanded several times.

In that conversation, she commented that she would not be using groups if Nancy and another teacher in the program had not given her such a hard time about still having her room in rows. Although she was forced to make these changes initially, in each of these examples she indicated in some way that she would continue to work toward improving the use of the specific change. While Nancy is internally motivated to make changes, Lorraine's motivation comes from external sources.

Jonily's motivational issues were similar to Nancy's, while Nicole's are similar to Lorraine's. Instead of gaining ideas from reading, Jonily gathers her ideas by participating in classes and programs, but her motivation to change is driven by internal pressures. Nicole's habit of collecting activities to use in her classroom is very similar to Lorraine's lack of interest in theory. Nicole is exposed to the activities and begins to think these are the kinds of things she is supposed to be doing in her classroom, without evaluating the theory or reasons behind using the activities. Nicole's desire to please others puts her in a position to use the things she thinks she is expected to use.

The teachers attributed the majority of the changes to the professional development program. However, two of the teachers found ideas in the program that resonated with ideas with which those teachers had already been experimenting. For instance, Nancy and Jonily both had explored discourse in their classroom prior to entering the program, although with a different focus than that eventually developed in the program. When discourse was first presented in the program, these two teachers quickly sought to implement those ideas. Lorraine and Nicole, on the other hand, found the ideas in the program interesting, but neither teacher formed an immediate attachment to any of the ideas presented during the program.

I have made the distinction between these teachers more clear than it is in reality. Nancy and Jonily both indicated a tendency to regress in their efforts occasionally and both gave examples indicating that the external motivation provided by courses or workshops encouraged them to try something that they might not have done on their own. Lorraine's use of the graphing calculators seemed to be something she greatly enjoyed and which was internally motivated. Although she took a class on how to use the calculators, she decided to take the class because she wanted to learn about the calculators. The opposite was not true; she did not become motivated to use the calculators because she had taken a class. While the lines are blurry, the general nature of these teachers is distinct. One group of teachers is internally motivated to seek out ideas, examine those ideas, and implement ideas in their classroom. Another group of teachers is externally motivated to make changes in the classroom because of other people's expectations. The teachers in this study made changes when they were put into situation that provided the kinds of motivation they most desired.

One additional interesting observation concerns the action research projects these four teachers completed. Although the focus of the second year was on their action research projects, none of the teachers listed research as a habit they planned to continue. Nancy discussed research in an informal way, but was referring to reading journals and magazines and not to doing classroom-based research. The program tended to focus on teaching practices with an emphasis on changing those practices. From listening to the participants talk about their action research project, they did not perceive these projects as an examination of their teaching practices. Going through the research process was not in and of itself a learning experience for them and none of these four teachers intend to repeat this process on their own. Instead, their perception seemed to be that they were using this research as a one-shot effort to show that their efforts to change one of their teaching practices had been successful. Somehow they missed the point of action research being a tool teachers can use to gather student feedback during an effort at changing teaching practices.

CHAPTER 6

THE CYCLE OF CHANGE

In this chapter, I will discuss the proposed Cycle of Change and how the teachers progressed through this cycle. Using the stages of the Change Cycle as a guide, each stage of the cycle will be examined and evidence of each teacher's progress through that stage will be provided. Within each stage, the teachers' successes and struggles with the necessary skills during that stage will also be discussed. The examples for this chapter are not necessarily pulled from the case studies in the previous chapter, although some of the examples do overlap.

During the final interview, I presented the Change Cycle Model (see Appendix A) to each teacher. After explaining the details of how they cycle worked, I asked each teacher how well the model fit with their experiences. All of the teachers agreed that the cycle accurately described their experiences and none of the teachers suggested any changes to the model. Nancy responded, "I think that it definitely fits what I go through a lot and some of them are more formal than others" (January 22, 2004). Nancy commented that she often proceeded through this cycle informally, without recording her goals or the progress toward those goals. Jonily's response to the model was enthusiastic. She had described in an earlier interview her struggle with communicating clearly to other teachers about the process of changing her teaching practices. When asked how the model fit her experiences, she said:

> I think it describes it perfectly. I have a hard time. When you asked me all these questions as we've done the interviews before, I have a hard time putting into words what I do and how I do it and I look at this and I say okay, this is exactly what I do. I don't know why I wasn't able to come up with that but this is a good picture of what I do. And sometimes the vision, the inquiry, the mastery sometimes there's something that can happen in one day and sometimes it takes 3 weeks but I think this is a perfect description (January 14, 2004, Final Interview).

Nancy and Jonily had connected the model to what they had done in their classroom, but did not initially connect the model to the program. Nicole's first comment did connect the cycle to the program:

> Well, I feel like Dr. Pape kind of led us through this. We talked about what we wanted to work on and then we developed an inquiry project. So I feel like this is very similar to how he helped us (January 14, 2004, Final Interview).

However, unlike Jonily and Nancy who said they could identify with all of the phases of the model, Nicole said that she had not had much success moving into the mastery phase. Lorraine also commented on the mastery phase. She gave a brief initial answer, saying that she thought the model was good, but went on to add that she did not often feel she could move into the mastery phase.

I asked each teacher to describe an example of going completely through the process. Jonily described her change in the use of one particular patterning problem and how she had generated more mathematics from the problem each year, until she had finally reached an open-ended approach that she felt maximized the potential of the problem. Nancy referred to the paper she had published on discourse and explained how she had worked through the course to change the discourse in her classroom. Lorraine offered graphing calculators as an example of having to learn how to use them herself, and then working to use them in her classroom. She noted that she was comfortable helping other teachers with the calculators. Nicole was the only participant who did not describe a complete rotation through the cycle. She offered many examples of forethought and inquiry, but was unable to find an example in which she had transitioned into mastery.

Not only were the teachers able to provide examples of moving through the stages of forethought, inquiry, and mastery, but the data collected over the four year period is also rich in examples. Therefore, in the next section of this chapter, I will explore each stage of the cycle and provide examples from multiple sources detailing how the teachers moved into and through each phase.

Vision/Forethought

I have chosen to enter the cycle at the vision/forethought stage. During the first year of the program, the teachers were periodically asked to identify goals for the quarter. At the end of the first year, each teacher had selected a topic for their action research projects. For all of the teachers participating in this study, the topic of the action research project became the focus for change that year: Nicole, questioning; Nancy, discourse; Lorraine, homework procedures; Jonily, writing. These topics were identified as changes they made in their classrooms during that year. For year three, Nicole, Nancy, and Lorraine all mentioned that their goal was to finish their masters degrees. Lorraine also mentioned that she had observed in another teacher's classroom during year three, as a requirement for a course. These observations served as motivation to moving her classes into groups at the start of year four. Jonily mentioned her involvement with curriculum development and projects in her school as motivation for her continued movement toward a reformed classroom during year three. For year four, the year during which my observations occurred, Jonily was the only teacher who stated a specific goal; to create a unit on rates and to modify the units she had already created. She related this goal to the course on assessment she was taking during the year. The other teachers talked about changes they wanted to make, but did not state any specific goal or timeline for those changes.

Nicole's discussion about goals differed greatly from the other three teachers. The specific goals that Nicole stated during the program or during my interviews were doing her research project on questioning, finishing her masters degree, and bringing "Math Court" into her classes. The first two goals involved doing things that were mandated by other people. "Math Court" was the only goal that Nicole had collected outside the professional development program boundaries. As discussed earlier, though, the use of "Math Court" followed Nicole's pattern of collecting activities she could bring into her classroom without giving thought to how she would need to change to incorporate that idea. Generally, during the interviews, Nicole indicated that she felt responsible to try everything and often became overwhelmed by that prospect. During the final interview

(January 14, 2004), I continued to ask Nicole if she could describe an example of moving into the mastery phase. She started talking about questioning, but said that she was still working on that. Later, at my suggestion, she started to explain a project she had used for several years, but then explained that she was still working on making that better. She explained at one point that she just kept finding ideas that she wanted to try in her classroom, and often felt overwhelmed at the prospect of so many new ideas to try. She appears to have trouble focusing on one aspect of her teaching. This inability to focus on anything specific contributes to Nicole's impression that she has not moved into the mastery phase of anything.

Whether or not goals need to be stated in a formal way seems to depend on the individual teacher. Nancy talked about her past goals, mentioning that some of her past goals were informal. During the final interview (January 22, 2004), she explained that some of her past goals had just been ideas she had found that she wanted to try in her classroom. She then went through the inquiry process without any formal documentation or formal processes. She also provided examples of times when her goals were established in a more formal process, such as the school-wide goal of writing across the curriculum. These more formal situations required written goals, and had more built-in accountability. During the interview, Nancy clearly indicated that she was able to follow through on goals whether they were formally or informally established.

Lorraine stated goals, such as changing homework practices, finishing her masters degree, and increasing the use of groups in her classes. For Lorraine, accomplishing these goals had little to do with whether they were stated formally or informally. Rather, Lorraine clearly stated on several occasions over the four year period that she requires external accountability to accomplish her goals. Lorraine actively spoke of the support the other teachers in the building provided for her throughout the program (Summer 2000, Bio; Autumn 2000, Class Evaluation; January 22, 2004, Final Interview). These teachers offered her support, such as reminders about assignments and a group to work with on projects, and to provide general encouragement (January 22, 2004, Final Interview). Early in the program, Lorraine wrote, "I need someone to evaluate me when I make some of my teaching changes and to keep me motivated to keep going when the changes seem overwhelming" (Summer 2000, Class Evaluation). This indicates that not only does she require external support, but she also requires external motivation to establish and accomplish goals. As I was coding Lorraine's data, a theme developed in the data that I labeled "I keep getting the feeling that she will only change if people force her to." The items coded this way indicated that she was motivated to make changes when other people whom she respected had expectations for what she should be doing in her classroom. These situations were all formal settings, such as college courses taken with other teachers in the building, or having a student teacher who was working with a professor she respected. The following quote summarizes Lorraine's need for accountability:

> But that's how I think a lot of change is. While I was taking classes you think oh it's an assignment. I've got to try this; I've got to change, I've got to do something and you know somebody is going to be asking you about it later. It's

so much harder to make a huge change in the class when it's just you (January 22, 2004, Final Interview)

The exception to this need for formal accountability was the change she made in grouping her students, motivated by the comments of other teachers in her building. This was not a formal situation, but she did greatly respect those teachers and had been involved in a formal setting, the program, with them.

Jonily never mentioned formally working on goals, but she did connect all of her examples to committees, workshops, classes, or building efforts at some point during all of my interviews with her. For example, she had a goal to use better problems that included more mathematical concepts within one problem. Because of this goal, she was attracted to a course offered through her district. Through this course, more problems were made available to her, and she was involved with a group of teachers who were also using these problems in their classrooms. These teachers met on a regular schedule with specific assignments connected to these problems. This leads me to conclude that Jonily requires some accountability behind her goals, although she does not require external sources to establish her goals. She appears to be choosing to participate in these activities to provide the accountability she craves.

Inquiry

In the inquiry stage, the first step is to take some action in the classroom. This step is titled "enact." All of the teachers gave examples of this stage of the cycle. Nancy and Lorraine gave examples of enacting changes during their teaching careers, even before entering the program. The second and third pieces of the inquiry cycle are performance control, which occurs during an attempt to enact the change, and self-reflection, the process in which decisions are made about future modifications. Jonily, Nancy, and Lorraine all provided multiple examples of going through all three stages of the inquiry cycle. Nicole was unable to articulate an example of going through all three steps of the inquiry stage. In this section, I will describe one example each for Nancy, Lorraine, and Jonily of their experiences going through the inquiry stage.

Nancy's Example of the Inquiry Loop

As an example of going through the inquiry stage, Nancy described her adventures with changing the discourse in her classroom. As she explained what that process was like, she offered the following description:

> Because there was never a time where—like when I first started doing more discussion there was never a time where there was like every single day it went badly. There might have been times where the kids were more willing to discuss or some of the hands on activities went better. Some of them were just better activities or discussions than others—some of it made better material than others. . . . at the beginning they would give short answers or they would say "I got this" and "Why did you get that?" You started to see results fairly quickly of them starting to improve (January 22, 2004, Final Interview)

This quote demonstrates Nancy's ability to analyze her teaching. Early in the program, Nancy decided to work on her classroom discussions. She set a goal to make the discussions more student-centered and determined steps she would take, such as using activities differently or having the students share their thinking in small groups before starting a whole-class discussion. In the previous quote, we see evidence of the performance control and self-reflection steps when she said “you started to see results fairly quickly.”

As discussed in the previous chapter, Nancy realized that some of her students were not participating in the classroom discussions. As she was conducting discussions, she was mentally noting the students who were participating. This is an example of the self-observation done during the performance control step of the inquiry stage. By self-reflecting on patterns she observed during the lessons, she self-judged that the lack of participation was something she wanted to change. She decided to start using small group discussions, an example of self-reaction in the self-reflection step. With this new idea in mind, she moved back to the enact step, and started again.

During the performance-control step, Nancy not only observed the patterns of participation, but she also attended to the kinds of questions the students were asking of each other, as explained in the previous quote. As she heard students ask each other questions like “how did you get that?” she judged the lesson successful. Using the self-reaction subprocess, self-reaction, she noted her satisfaction with how the students were interacting. During the self-reflection step, Nancy reflected on the lesson, and again, using self-reaction, determined the use of groups successful. While she was monitoring her use of groups, Nancy was also monitoring the activities in which the groups were involved. As she indicates in the previous quote, on any particular day the groups might have functioned well, but the selected activity was found lacking. Therefore, Nancy stayed in the inquiry stage working on many different features of discourse simultaneously. It was not until she felt like she had considered all the components contributing to the discussion that she moved into the mastery phase. For Nancy, this process took three years. Although she started the second year thinking she had moved into the mastery stage with discourse, she quickly realized that she had neglected the impact of establishing classroom expectations. This caused her to move back into the Inquiry stage, where she began the enact step by talking to the students about her expectations for discussions. Nancy seems to have moved into the mastery stage sometime during the third year of her work on discourse. It may be that the research project she did provided additional confirmation of her success, convincing her that she had sufficient knowledge and mastery of the use of discourse in her classroom.

Lorraine's Example of the Inquiry Loop

One of the examples Lorraine gave of using the inquiry stage involved a recent lesson she taught while a student teacher was in the room (January 22, 2004, Final Interview). The lesson was on drawing three-dimensional figures given different viewpoints of the figure. Although she had covered three-dimensional shapes in previous years, this lesson was different from what she had done previously. This lesson was designed to build on what Lorraine had observed in one of the seventh grade teacher's classes. In the seventh grade class, the teacher had provided students with three-dimensional figures and had the students draw the top, bottom, front, back, and side views of the figures. One of Lorraine's goals is to use more hands-on activities, and this lesson was designed to give students some additional experience with three-dimensional objects by building on what the students had done in their seventh grade mathematics class. In this lesson, the students were given the top, left, and right views of the object and were asked to draw the three-dimensional shape. Lorraine entered the enact step when she taught the lesson. As she explained, the lesson was a disaster when she first taught it with the fourth period class. “I was like that was the worst—not the worst thing I’ve ever done but probably that, it’s pretty up there” (January 22, 2004, Final Interview). This is an example of Lorraine using performance control during a lesson. As she taught the lesson, she was observing how the lesson was going. Lorraine talked about feeling frustrated during the lesson because the students were unable to visualize the objects using the given views. As she observed the lesson, while teaching the lesson, her self-judgment was that the lesson was not going well. This judgment was based on her feelings of frustration. Her self-reaction during performance control was a desire to not experience those feelings of frustration again. After the class, she and the student teacher talked about the lesson and Lorraine decided that the lesson would have to be modified for her afternoon classes. Talking about the lesson with the student teacher after class indicates that Lorraine had moved into the self-reflection step of the inquiry stage. During self-reflection, her self-judgment included the input of another person, and resulted in reaching the same conclusion that the lesson had been very frustrating. Her self-reaction resulted in a change of focus for the lesson. Instead of starting with different viewpoints, such as the top or the front, she decided to give the students pictures of three dimensional objects and have the students draw the different viewpoints, going back to the same activity the seventh grade teacher had done. Lorraine spent her lunch time searching the Internet for pictures of three-dimensional objects and then proceeded with the modified lesson for the sixth period class. Although Lorraine did not talk about what she was thinking as she taught the lesson to sixth period, the fact that she could reflect on the lesson after it was over and make judgments about the lesson indicates that she did go through the performance control step while she taught sixth period. When that class ended, she talked with the student teacher again, demonstrating movement into the self-reflection step again. Lorraine decided that the lesson would need further modification for the fifth and eighth period classes who would experience the lesson the next day. For those classes, Lorraine decided the students just needed to practice drawing three-dimensional shapes. Upon teaching this revised lesson the next day, she had moved back into the enact step.

Jonily's Example of the Inquiry Loop

During the November 6, 2003 observation in her fourth period class, Jonily gave a warm-up problem involving calculating the cost of a weekly car rental for different rental companies. One of the problems asked the students to write a formula that could be used to calculate the rental cost. As students shared what they had written, Jonily wrote the formulas on the board. As she was writing, she began to realize that although all of the formulas offered looked different, some of them were just different representations of the same situation. Some of the formulas correctly modeled the given problem, albeit in different formats. Other formulas did not model the situation. As she listened to the students' explanations of how they arrived at their formulas, she began to understand that the students were seeing all the formulas as different and were not considering the possibility that formulas could be written in different ways. The period ended soon after students offered their explanations. Jonily shared with me after that class that she had not considered that possibility that the students would come up with so many different representations of the same situation and that she was trying to find a way to deal with this. Her realization that the students were not seeing the formulas as potentially the same was an example of self-observation during the performance control step of the inquiry stage. As she stood in front of the class in the middle of the lesson and decided that this lack of differentiation on the part of the students was a problem, she was still in the performance control step, but was now using the subprocess of self-judgment; she had made a determination that the lesson was lacking in some way. As she talked about the problem between periods, she moved into the self-reflection stage of the cycle. Her thoughts, as she verbalized them, reiterated her decision that the lesson was lacking, an example of self-judgment during self-reflection. Still reflecting on her lesson, she used the self-reaction subprocess to determine that she would need to pose some questions to the students to encourage them to think about the possibility that the formulas offered by students might actually be the same formulas. Jonily started the sixth period class with a new plan, moving her back into the enact step of the inquiry stage. In that class, she had the students share their formulas for one part of the problem. As with the previous class, these formulas looked different, but some were actually correct representations in different forms. Jonily then asked the class how they could determine if they formulas were the same or not. Upon reaching this point of the lesson, she moved into the performance control step, where she would actively monitor how the change in the lesson progressed. The students made suggestions to her about what they could try to compare the formulas. Although I was not able to access her thinking right at that point, the fact that she allowed the discussion to continue indicated to me that she had judged her questions as having moved the discussion where it needed to go. Class ended before the students could finish evaluating the formulas. After the class, moving into the self-reflection stage, Jonily self-judged the questions as having accomplished her goal of getting the students where she wanted, but in a leading way with which she was uncomfortable. She felt that the questions were too leading. She determined that the next class she would end the discussion after the students offered their formulas and ask the students to consider the formulas as homework. She wanted to see if any students would bring up the topic of comparing the formulas the next day without her having to lead them to that conclusion. Her determination to change how she was going to handle the last class of the day was an example of the self-judgment and self-reaction subprocesses during the self-reflection stage. Through this one example we have seen how Jonily monitored her lessons while in the midst of the lesson, how she identified problems with the lesson, how she reflected on any problems, and modified her attempt with the next period. She made judgments about how the discussion allowed for the generation of mathematical ideas and determined that a change was needed.

Comparisons of Nancy's, Lorraine's, and Jonily's Inquiry Loop Experiences

A comparison of Lorraine's and Nancy's comments related to performance control and self-reflection provides interesting insights. As I have argued earlier, all three of these teachers proceeded through each phase of the Inquiry loop. However, Lorraine's comments show that her decisions while in that loop were based on her feelings and experiences. Nancy and Jonily, on the other hand, tended to make decisions based on what they determined their students were experiencing and feeling. For example, as Lorraine was explaining the lesson about three-dimensional objects, she commented:

> I told him - I said I will have to change this for the afternoon because I can't do that again. So during lunch I'm going to figure out something different to do and I was on the internet trying to find pictures as fast as I could. Finding 3-D shaped pictures that I could use. Because I could not do the same thing twice. It was going to be way too painful for me (January 22, 2004, Final Interview)

In that one response, she pointed out twice how she was experiencing the lesson, but not how the students were experiencing the lesson. This was a pattern in her analyses of lessons. She would state whether or not she thought the students understood the lesson, but she would not delve any deeper into why the students did not understand. The data indicates that although Lorraine does travel through the Inquiry cycle, she does not use student learning or student input to analyze the lessons and make decisions about further changes. Instead, Lorraine's decisions are focused on what the teacher is experiencing.

Lorraine's teacher-centered decision making process is very different from Nancy and Jonily's student-centered process. Nancy and Jonily occasionally comment on how they felt about a lesson personally, but they tended to base their comments on student behaviors rather than their own feelings. For example, when Nancy was explaining how she had learned about using discourse and how she tried to implement student-to-student discussions during the first year of the program, she said:

> I specifically would come in here at that point, when I would read about a technique and actually try it and not be sure how it's going to go, and when I'd see success with it with the kids that that truly worked. They were truly agreeing, disagreeing. They were giving mathematical justification then I was spurred on to keep evolving with that (October 30, 2003, Preobservation Interview)

In this quote, Nancy talked about student behaviors, such as agreeing and disagreeing with each other. Throughout her journals, reflection papers, and my interviews with her, Nancy consistently tied her judgments about her attempted changes to student feedback and explained how her decisions were based on those student actions.

Jonily talked about the changes in her teaching in much the same way Nancy did, although Jonily was still more focused on her own actions than was Nancy. Nancy determined what she wanted her students to do, and then planned her actions to achieve that goal. Jonily acted and then assessed how the students responded to those actions. I will provide here a few examples that demonstrate how Jonily talked about trying to change her teaching. In the first quote, from late in the first year of the program, Jonily was beginning to make observations about her teaching by connecting her actions to the students:

> Most of the time I give/tell students the information they need to know. They are not actively engaged/involved. Many students also don't like math or aren't good at math. I think that the more students are involved the better they will feel about math and the better they will be at it. Many students who like math and do well in math still don't have a good understanding of math (Spring 2001, Journal 3)

This quote demonstrates the connection Jonily had made between what she did, telling students information, and what the students did, not being engaged. In the Final Interview (January 14, 2004), Jonily explained how she had modified a patterning problem she had been using over the last three years. In her explanation, she described the kinds of responses the students had given each year and how those responses had changed. Her conclusion that she was doing a better job using the problem resulted from her analysis that each year she said less while the students discovered more patterns within the same problem. She made a change, using mathematically rich problems and organizing the content into broader units, and used student responses to analyze the success of the change, and to determine future changes.

Nancy and Jonily had different approaches, bringing students into the decision making process at different points, but both used student feedback to assess the success of changes. Lorraine tended to rely on how changes impacted her personally. She used student feedback as a means to validate how she experienced lessons. The difference between doing performance control and self-reflection in a teacher-centered versus student-centered manner impact the kinds of decisions that are made and result in different choices being implemented during the enact step.

Nicole Offers A Counter Example

Nicole did not share any examples that exemplified her progress from the enact step into performance control, into self-reflection, and returning to enact. During the final interview, hoping to gather examples, I specifically asked if Nicole could describe an example of having gone through this process. She said that she felt like she had been led through the process with her research project but I could find no evidence that she had experienced performance control or self-reflection through her research project. In her description of her research project (May 2, 2002, Reflection 1), she stated that her support person observed lessons and tracked the level of questions. In the following quote from the Reflection, notice how the language she used places the ownership of judgments on “we” instead of “me”:

> We noticed that when students were able to relate to the activity or question, students were able to respond with more detail and explanation. We also noticed that I could oftentimes get a higher-level response if I persisted and encouraged students to explain their reasoning further. On the other hand, if I accepted lower-level responses, students tended to only offer this level of response. (May 2, 2002, Reflection 1)

Although collaboration can be an essential part of the inquiry process, Nicole’s language indicates to me that Nicole assumed a less active role in arriving at these conclusions. There are no explanations in Nicole’s Reflection 1, in any of her journal responses, nor in the interviews with her that demonstrate her taking ownership of the conclusions. This leads me to conclude that she was not self-regulating her practices and merely accepted what others told her about her practices.

To further substantiate this conclusion, Nicole often made comments indicating she enacted changes but then made little progress. For example, “I have made several changes in my classroom. These changes have not permeated all aspects of my classroom, but changes have been implemented” (May 16, 2002, Reflection 2). Another quote, which exemplifies many statements made by Nicole over the four year period, demonstrates this sense that she tried to make changes, but then did not know how to make further progress:

> I have not been able to completely change my questioning practices. I can preplan questions ahead of time, but most questions that are asked in the classroom are in response to student comments and questions and therefore, have to be formed on the spot. I guess this will develop with time and I will become better at asking question. I am not sure how else to become better in this aspect of my teaching (May 16, 2002, Reflection 2)

In the final interview, when I asked specifically for an example of going through changes, Nicole was not able to identify any big changes that she felt fit the model. I then asked her if there were small changes she could identify as examples. She responded by saying:

> When I initially started I wanted my topic to be—I wanted to find good lessons that actually—I wanted to find the best lesson to teach the concept. But that was kind of hard to do, the inquiry project on that and study it. So—so I feel like I'm still working on that, trying to figure out what's the best method for teaching this process. Is it give them a problem first and let them talk about it, figure it out then, go over it or is it manipulative or—. So I feel like I'm still with the circle with that too. I mean, I think I've improved on some things but I don't feel like I'm ready to move on from focusing on it. You know what I mean? (January 14, 2004, Final Interview)

Anytime she was asked to identify changes that she felt she had completed, she concluded that she had not really mastered the change. I propose that she is still stuck inside the inquiry loop because she is not able to maneuver through performance control and self-reflection. In a lack of self-regulation, she is not self-observing, self-judging, or self-reacting while she is teaching nor after she has taught a lesson. She has pulled in many new ideas, but she is not self-regulating their implementation. Because she is not self-regulating as she tries new ideas, she is not able to make judgments for herself about their implementation and their impact on her students. Without the process of self-regulation, little professional growth occurs.

Mastery

Nancy, Jonily, and Lorraine offered examples of times they felt they had moved into the Mastery phase. As I explained previously, Nicole was not able to provide any examples of moving out of the Inquiry phase, and consequently, had not experienced the Mastery phase. This section will describe the teachers' individual experiences with transitioning and experiencing the mastery stage.

Nicole

Nicole quickly stated a lack of movement into the mastery phase. After describing how she had been led through this process during the program, Nicole commented, "I feel like I'm still in this circle because I don't feel like I've mastered—I know I've improved some but I still feel like I . . . I'm still in the inquiry circle" (January 14, 2004, Final Interview). Lorraine and Nicole both used the word "perfect" when talking about the mastery phase. Nicole said, “But I feel like no one is ever going to be perfect” (January 14, 2004, Final Interview).

Nancy

Nancy offered her research topics as changes with which she had moved into the mastery stage. I asked her to identify how she knew she was in the mastery stage with a change. Nancy explained that the use of student-to-student discussions had become automatic for her, not requiring much conscious thought to make them happen or conscious evaluation to determine whether they were going well or not (January 22, 2004, Final Interview). She stated that when things become automatic, she considers that a signal that she could shift her focus in another direction. She also shared that having written the article and presented her experiences with discourse to other teachers made her feel confident that what she was doing in her classroom qualified as good teaching (January 22, 2004, Final Interview). Although she continues to monitor her use of discourse, her energy can now be directed elsewhere.

Lorraine

Lorraine’s response to the complete Change Cycle differed from Nancy’s, specifically in her interpretation of the Mastery phase. She answered, “I think that’s good except I don’t know how often I actually get where I think I can’t do better” (January 22, 2004, Final Interview). The first part of her answer, “I think that’s good,” almost seemed to be a judgment of the Change Cycle’s value. However, it is her immediate assessment of the mastery phase that I found informative. She saw the transition into the mastery phase as almost an arrogant stance. My first thought was that I might have described the mastery phase differently for Lorraine than for the others, in a way that led her to believe that “mastery” meant perfection. However, an analysis of my descriptions showed that during each interview I stressed that mastery meant the teacher having reached a level of comfort with the change at hand, resulting in a feeling that the newly implemented change was “working for you” (January 22, 2004, Final Interview, Lorraine). I began to examine the data to see if Lorraine demonstrated a difference in the level of confidence in her teaching.

A further analysis of Lorraine’s data did not reveal this to be the case. Lorraine seemed to have the same level of confidence that Nancy and Jonily had. However, Lorraine’s confidence appears to weaken and she becomes defensive when she has to directly compare herself to other teachers she respects. For example, when Lorraine talked about her on three-dimensional objects, the lesson analyzed in the Inquiry section of this chapter, she explained that the lesson had failed because eighth grade students are different from seventh grade students. In the end, the modified lesson was the same lesson Lorraine had observed the seventh grade teacher used. Lorraine attributes the failure of the lesson to some inherent differences between seventh and eighth graders. This is just one of many examples of Lorraine placing the blame for lack of success outside herself. I conclude that her failure to accept responsibility for failure is also preventing Lorraine from accepting responsibility for success. It is this inability to accept personal responsibility that is preventing her from moving into the mastery stage.

Jonily

Along with her research project, Jonily showed evidence of having moved into the mastery stage with her use of units and mathematically rich problems. During the pilot study, preobservation, and final interviews, and in our informal conversations during my observations, Jonily stated that she was confident that what she was doing with the units and the mathematically rich problems was working for her students and benefiting their development in mathematics (May 2003, Pilot Study Interview). Although she plans to continue improving her units and collecting additional problems, she sees herself has having mastered the big ideas behind using those kinds of resources. I witnessed her sharing ideas with the other eighth grade teacher about how to use one problem to cover many topics (September 3, 2003, Discussion), demonstrating her confidence in what she is doing. She is committed to using mathematically rich problems and had even committed to taking another course in the hopes of finding more problems. The fact that she is now beginning to focus on how she is assessing these units indicates that she has moved into the mastery phase of using mathematically rich problems, although she will continue to gather more, and is now ready to shift her focus to improving the assessment in her classroom.

Return to Vision/Forethought

In the previous chapter, I discussed the teacher's plans for future changes. These future changes indicate the transition back around to the Forethought phase. Although Nancy did not identify any specific changes, she indicated that she is pursuing the traditional avenues by which she gathers ideas, reading journals and educational magazines. Jonily described her plans to work on assessments in her classroom. Lorraine's and Nicole's future goals involved changes they had already started, indicating that Inquiry loop and have not traveled through the entire cycle completely yet.

Patterns of Change Behaviors

Comparing the teachers' experiences moving through the change cycle revealed several patterns of behavior. First, the teachers who made the complete cycle used similar sources of information to make decisions at any point of the process. Second, the ability to accept personal responsibility for successes and failures was also common factor in the teachers who moved into the mastery phase. The final identified pattern involved the identification of goals. The teachers who made a complete cycle had a method for identifying and determining goals.

The first pattern in decision making became apparent in the inquiry stage, where Nancy and Jonily both used student feedback to inform their decisions. Students are a ready source of information in the classroom. This source does not disappear at the end of a program, nor does it go away when time pressures prevent collaboration with peers. Jonily and Nancy had somehow learned to use the students as a source of information about what students are learning. Lorraine, and to some extent Nicole, used their own feelings about a lesson to determine the success of the lesson. Nicole also used the length of a lesson; did the lesson occur during the time frame she had allotted for the lesson.

However, while personal feelings were less effective during the inquiry stage, they appeared to be necessary to move into the mastery stage. This was another pattern in the decision making process. Both Nancy and Jonily moved into the mastery stage based on their own internal assessments and not because of external influences. Lorraine identified no source that would help her make positive assessments about her progress. Conversely, Nicole often expressed a need for an expert to tell her how she was doing, or to help her make decisions. Because Nicole lacked a sense of self, she did not complete the cycle.

The ability to accept responsibility for one's successes and failures was also a common factor in the teachers who moved into the mastery stage. Nancy and Jonily both identified actions they had taken and were able to articulate how those actions had resulted in changes in their students. Lorraine, on the other hand, often made comments indicating that she assigned responsibility elsewhere. For example, throughout the two year professional development program, Lorraine repeatedly used the short periods as a reason for not implementing ideas suggested in the program. Comments like "if only we had double periods you could . . . but it's hard to fit that in when you have such short class periods." (Winter 2001, Focus Group) were made continuously during her time in the program. With the removal of the time barrier, Lorraine now offers other factors as reasons for not implementing change. When asked to identify how she might be different from other math teachers, Lorraine said, "I have 75 students. That's a lot. That's just way too many kids. You cannot teach effectively and have that many students" (January 22, 2004, Final Interview). Although she has been given more time per day with students on the days she sees them, she still has all the eighth grade students. Another example of Lorraine placing blame on external sources includes her emphasis on homework. "Because students didn't complete the assignment, many times they don't understand the concept and don't know what questions they should ask" (Spring 2001, Journal 3). Lorraine does not talk about how her teaching methods or the activities she selected might have contributed to the students' lack of understanding. Instead, this quote indicates that students who do not understand concepts do so because they did not do something they should have done. While lack of time, high numbers of students, and students who do not do homework are all important issues, they are not such great stumbling blocks that change cannot be constructed inside their constraints. Lorraine, however, uses these issues as a protective shield, preventing her from having to take responsibility for the learning in her classroom.

The identification of goals was another area where the teachers differed. Nancy and Jonily both had clearly identified methods for input on new goals. Jonily enrolls in classes or workshops, or takes part in district initiatives. Nancy, who enjoys reading, uses educational magazines and journals, along with the Internet, for new information. Although these two avenues are different, both teachers have identified what they need to do to keep themselves motivated and informed. Lorraine often said that she needed to be held accountable by others to make things happen. However, as of the time of my observations, she had not arranged, formally or informally, for the guaranteed continuation of that accountability. Nicole's need for an expert to validate her actions is a difficult need to fulfill. One possible source for expert validation would be the other math teachers in Nicole's building who had also participated in the professional development program. Unfortunately, the reality of the school schedules makes it unlikely that those teachers could spend any quality time observing in Nicole's room. Nancy, Jonily, and

Lorraine all have needs that might be more easily fulfilled. Jonily and Nancy have taken action to meet their needs. Nicole's need for an expert is something that could be fulfilled, but also seems to me to be something in need of adjustment.

Summary

In this chapter, I have examined how the teacher progress through the proposed Change Cycle. Examples were provided describing the teachers' experiences in each part of the cycle. From this examination, important patterns were recognized. For teachers to feel empowered during the process of making change, they must be able to self-regulate their teaching. Being able to monitor one's practice and to participate in the subprocesses of self-observation, self-judgment, and self-reaction appear to be essential components in making lasting changes. Using student feedback, versus using the teacher's feelings, appears to be important during different parts of the cycle if teachers are going to self-generate change. Being able to accept responsibility for successes and failures in the classroom is important in being able to move into the mastery stage, a move that is vital for creating generative change. Finally, teachers who have a method for establishing goals notice more success moving back into the vision/forethought stage than do teachers who just adopt goals given to them.

CHAPTER 7

CONCLUSIONS AND IMPLICATIONS

Professional development providers have long sought to create programs to help teachers change their practices. Reform-minded programs promote change by focusing simultaneously on increasing teachers’ knowledge of student learning and on the teachers’ mathematical knowledge. Programs have more traditionally sought to support teachers’ efforts at change by introducing teachers to new ideas. However, teachers were often sent back to their classrooms to experiment with the new ideas on their own. Reform-minded professional development programs create a supportive environment by providing extended time for exploration. The time lines for reform-minded programs are months and years, rather than days and weeks. The extension of time makes possible the creation of a trusting environment where teachers can share their successes and failures, and seek additional support. The long duration of reform-minded programs also provides the time for teachers to try ideas in their own classrooms and then analyze those classroom experiences with other teachers, whom they have come to know and trust. The use of support personnel in the teachers’ individual classrooms provides the participants the opportunity to use feedback from their own students to inform their changes. The program in which the four teachers in this study participated was clearly a reform-minded program. After being together for two years, supporting each other and receiving support in their classrooms from program providers, the teachers could identify many changes they had made in their teaching practices. This study was an effort to describe those changes and how they occurred. This study also dealt with how teachers were encouraged to continue the process of change outside the supportive environment of a reform-minded program.

Summary and Conclusions

In this section, the research questions for this study are reviewed and the broad findings for each question are restated. This summary examines the teachers as a group rather than as individuals.

Findings for Research Questions 1 and 2

The first two research questions inquired into the specific changes made by the teachers during and after the program, which changes were new, which were sustained, which were not sustained, and the reasons for those changes. This study confirmed findings of previous studies and resulted in additional insights into change.

As found in other research projects (Borko, et al., 2000; Crockett, 2002; Franke, et al., 2001; Jones, et al., 2000; Manoucheri, 2001; Smith, 2000; Swafford, et al., 1999), the teachers made changes aligned with the goals of the program. The common changes made by all the teachers were changes in classroom discourse and changes in the utilization of groups and hands-on activities and clearly reflected the program goals. All four of the teachers in this study demonstrated changes in their thinking about mathematics and the teaching of mathematics, although these changes occurred in varying degrees and at different points in the program. Some of the teachers also demonstrated the habit of using the language of reform before implementing the corresponding actions (Senger, 1998-1999). A teacher's familiarity and past experience with an idea greatly impacted the speed and degree with which the teacher sought to implement any specific idea in her classroom. As in Crockett's study (2002), different activities challenged the teacher's beliefs differently. In the study presented here, some of the teachers became conscious of beliefs and attitudes that were preventing progress, while other teachers did not realize how their beliefs conflicted with the attempted changes.

This study also confirms the importance of content knowledge in developing reform-minded practice. As explained earlier in the literature review, teachers need to know the mathematics they teach in a flexible, conceptual way (Borko & Putnam, 1996; NRC, 2001). The teachers in this study who understood mathematics in mostly a procedural way, or as Thompson, Phillipp, Thompson, and Boyd (1994) called calculational knowledge, made less progress in their efforts to move towards reform measures. Their lack of conceptual understanding prevented them from making connections within the content, limiting the teachers' success with discourse in their classroom. Not knowing the mathematics in a conceptual way limited the kinds of questions the teachers could ask as classroom discussions occurred.

As found in the literature supporting this study, the beliefs held by teachers influence how teachers implement new ideas (Borko and Putnam, 1996). Some of the teachers in this study made little progress as they tried to implement new ideas because their beliefs about teaching mathematics limited their implementation of the new ideas.

Apparently, for those teachers, the discussions and experiences in the professional development program, did not create a dissonance between the teachers beliefs and their desired actions. Those teachers did not become cognizant of the conflict between their beliefs and the actions they were trying to take. This study demonstrates that reform-minded professional development does not necessarily create the Deweyan dilemmas (Crockett, 2002) necessary to challenge those beliefs for all teachers.

Because the existing literature was lacking in longitudinal studies, the research literature did not contain examples of teachers who implemented reform ideas after an extended period of time. This study provides such an example. A full year after completing the program, a change in environment occurred that allowed Lorraine to begin implementation of the ideas valued in the program. Lorraine participated in the two-year program and taught the year following the program without making substantial changes in her teaching. A change in her teaching schedule after her participation in the program allowed her to begin the exploration of reform-minded practices in a substatial way.

Along with not necessarily challenging the beliefs of all participating teachers, reform-minded professional development practices do not teach teachers how to self-evaluate their beliefs. In the process of making change, comparing one's beliefs to the beliefs underlying a desired change is important. If teachers are going to create self-generated changes in their teaching, they must continue this comparison of beliefs on their own. In this study, the teachers did not indicate that they had learned how to do this by themselves. The program created dissonance for some of the teachers, but those same teachers showed no evidence of having learned how to change on their own. .

Findings for Research Questions 3 and 4

Thinking of the who, what, when, and where questions that often drive investigations, we see the first two focus questions for this study concentrated on what and why questions; what changes did the teachers make, sustain, or eliminate, and why. The third and fourth focus questions for this study centered on the how questions; as the teachers made changes, how were those changes accomplished. The third focus question sought to explore how by comparing the teachers' experiences against the proposed model for change (see Appendix A). The fourth question inquired into the patterns in the teachers' dispositions to reflection, continuous change, and their thinking about mathematics as a way of understanding how these teachers made changes.

Although the director of the professional development program did not model the program on the Change Cycle (see Appendix A), the program did enact the model. All of the teachers identified examples of the vision/forethought stage at some point during the program, and one teacher provided evidence of a concrete goal for future changes. All four of the teachers felt that their program experiences had walked them through the enact, performance control, and self-reflection stages. The use of videotaping and reflective journal writing is one example of how the three steps of inquiry were implemented in the program. Three of the teachers discussed multiple examples of looping through the inquiry stage. The one teacher who was unable to provide examples of going through the steps of the inquiry stage demonstrated an inability to self-regulate her teaching. She did self-observe, self-judge, or self-react during or after her teaching. Instead of relying on her internal self-monitoring, she evidenced a tendency to rely on other's assessments of her performance.

Movement into the mastery phase appeared more difficult. Only two of the teachers were able to move into the mastery phase, and then move on to identifying future goals for change. The research project was one aspect of the program that I had anticipated would serve as an impetus for moving the teachers into the mastery phase. Only one teacher specifically cited her research project as contributing directly to her ability to move into the mastery stage. Two other teachers provided examples that were not directly related to their research projects. Of the three teachers who described experiences of moving into the mastery phase, only two of these teachers moved back into the vision/forethought stage, where they continued to generate changes in their practices.

One of the reasons two teachers were unable to move into mastery stage may be that their self-efficacy for making changes in their classrooms was sufficiently lower than the teachers who did successfully move into the mastery stage. These two teachers were not able to credit their successes to themselves, and did not see themselves as having "mastered" any part of the goals set forth in the professional development program. An incomplete knowledge of the mathematical content was another factor which prevented movement into the mastery phase. Incomplete knowledge of mathematics can surely impact a teacher's self-efficacy for improving teaching in a mathematics classroom. Low self-efficacy can impact a teacher's ability to acknowledge personal successes. Various other interactions between the findings in this study are possible. The cause and effect nature of these issues are worthy of additional investigation.

Along with low self-efficacy for making changes, and incomplete mathematical knowledge, the two teachers who did not move into the mastery stage also failed to demonstrate the use of student feedback as a tool to inform their teaching. These teachers reacted to lessons based on their own feelings and did not reference student behaviors as a source of information. The other two teachers who did move into mastery talked about using student comments and behaviors as indicators of the quality of lessons and activities. The difference between the kinds of input had an impact on the kinds of conclusions the teachers were able to make.

Teachers can be working on multiple goals at the same time. These goals may or may not be related to each other. The Change Cycle proposed here assumes that as teachers complete one cycle and move back into the vision/forethought stage, that the subsequent goal will be connected to the previous goal in some way. During the inquiry stage, the teacher may be identifying ideas for future goals. Therefore, teachers must complete the inquiry cycle and move into the mastery phase for one goal before a subsequent related goal can begin. This means that if teachers never move out of the inquiry stage for a goal, further progress on subsequent goals can never begin, and thereby preventing generative change. While teachers may be working on several goals simultaneously, the idea of generative change requires that the teacher complete one goal and create a new goal as a result of the previous effort.

The two teachers in this study who were unable to identify examples of having moved into the mastery stage were also unable to demonstrate evidence of future goals that exemplify generative change. Therefore, I conclude that helping teachers move out of inquiry and into mastery, by helping them become cognizant of their accomplishments, is a necessary component professional development programs. Additionally, professional development programs must also do this in an overt way, helping teachers learn these skills so that the teachers learn to self-identify their accomplishments.

Reform-minded professional development clearly encourages change in teaching practices, but this type of professional development does not go far enough to impact the ways teachers approach the change process. This study compared the patterns of change exhibited by the teachers throughout the program to the teachers' stated plans for future changes. No evidence appeared to indicate that any of the teachers modified the way they approached change. The teachers had the same approaches to tackling change when they left the program as when they entered the program. This study shows that reform-minded professional development based on extended, supportive, reflective, and mathematically enriching experiences does not necessarily impact the ways teachers approach the process of making changes in their teaching practices. These programs are not developing the skills that teachers need to become self-generators of change.

Implications for School Administrators

In working with teachers and planning professional development opportunities for a part of the faculty or an entire building, administrators need to first identify the purpose of the professional development. Using Smith’s (2001) ideas of transformative versus additive, administrators need to identify whether the program is intended to add to the knowledge teachers possess or if the program is intended to transform the teachers. If the program is intended to be additive in nature, then short-term information sharing settings may be appropriate. However, if the intent is to transform teachers, then administrators should make long-term goals that are open-ended enough to allow for teachers' personal visions and interests.

If administrators want to have the additional goal of helping teachers continue to generate change, then administrators must become aware of the importance of self-regulation in the change process and create situations where teachers can learn how to self-regulate. This may include teachers observing each other to provide specific kinds of feedback, studies of student work centered on gathering information about how changes in teaching practices impact students, or other organized instruction on self-regulation. These activities would be conducted as part of the larger professional development process and should be used to inform teachers' about their individual goals.

Along with helping teachers learn how to self-regulate, administrators interested in generative change should also encourage authentic opportunities for teachers' acknowledgment of accomplishments. To move into the mastery stage, teachers must become aware of and acknowledge the successes they have with change. Administrators can provide opportunities for teachers to talk with each other about those successes, provide forums for teachers to share ideas across subject areas, grade levels, and buildings. Administrators can also encourage teachers to present ideas at professional conferences by creating a culture that encourages attendance and participation in such events. However, I stress that meeting teachers at their individual comfort levels is important. Each teacher should be encouraged to acknowledge their accomplishments in a way that is authentic and at least moderately comfortable for the teacher.

Changes Lorraine made after the school blocked the eighth grade mathematics and science classes point to an important factor in teachers' abilities to change. Although Lorraine was not given more time with her students, the arrangement of those minutes was modified in a way that allowed her more quality time with her students. The impact of this change in schedule is important. As administrators consider the structure of the school day, teachers' requests for more time with their students might be answered by considering alternative structures of existing time.

Implications for Professional Development Providers

If reform-minded professional development is done well, as was this program, great amounts of change occur. However, those evaluating the program should be wary of making immediate judgments about how much change has occurred. As this study has shown, teachers may sit on ideas for extended periods of time before they actually begin to implement the ideas. As evidenced by Lorraine, some teachers need a change in their school environment before they implement new ideas. Professional development providers either need to be prepared to take an active role in helping teachers change their school environments, or be prepared to wait for those environmental changes before making conclusions about whether or not a teacher has made changes as a result of program participation. Teachers who have not made substantive changes at the end of a program may not be lost causes. They may be waiting for a necessary environmental change, at which point the teacher can then enact the lessons learned in the reform-minded professional development program.

The inability of reform-minded programs to challenge teachers' beliefs, or to make teachers aware of their conflicting beliefs, was apparent in this study. The question of how such programs can push teachers to examine their beliefs about teaching while still creating a safe and nurturing environment for change is a question of balance. A recommendation I would offer for program providers is to encourage support personnel to analyze in detail the individual teachers' responses to inventories examining beliefs and self-efficacy issues. By comparing individual teachers' responses to such inventories, support personnel could help teachers compare their actions with stated beliefs. This is one way to use teachers' own responses and behaviors as evidence of conflicting beliefs.

Teachers can be taught how to self-generate change. The two teachers in this study who provided examples of self-generating change stated that the Change Cycle model exemplified the steps they had taken to make those changes. The skills needed to navigate through the Change Cycle can be taught. Therefore, just like we teach other ideas, the concept of generating one's own change can be taught. By making the stages and steps obvious, teachers can be taught how to identify goals, self-regulate their implementation of steps to accomplish stated goals, identify mastery of stated goals, and reflect on those achievements to identify future goals.

The two teachers who did not appear to have successfully moved into the mastery stage both struggled with beliefs and dispositions that were in conflict with the changes they were trying to make. This highlights the importance of helping teachers identify their beliefs. Professional development providers have a responsibility to help teachers realize how their beliefs may be in conflict with the goals they may be trying to implement. Encouraging teachers to pursue goals that directly conflict with held beliefs sets teachers up for failure, which may decrease their self-efficacy for making changes. To prevent a self-defeating cycle, professional development providers must help teachers identify their beliefs about content and teaching that content. Professional development providers should work with teachers to help them understand how those beliefs conflict with the goals for change identified by the teachers.

This study supported the existing literature regarding the impact a teacher's beliefs have on the teacher's ability to change. Professional development programs must extend how they deal with beliefs. While helping teachers realize conflicts between beliefs and goals is important, it is also necessary to teach teachers how to come to these realizations on their own. To develop in teachers the skills of self-generative change, teachers must be prepared with the necessary tools for examining their beliefs. While this examination might happen with external support, teachers need to learn how to make it happen themselves. Challenging of beliefs should become an overt part of professional development so that the process of comparing ones beliefs to desired changes also becomes explicit.

Additionally, reform-minded professional development programs do not currently include an overt component to help teachers identify whether the teachers work better with internal or external motivations for change. Nor do these programs help teachers identify future situations that would likely provide that type of motivation. In this study, for example, Jonily thrived on external accountability to make the changes she was internally motivated to make. Although she continues to find those kinds of opportunities, the *Teacher-Researchers* program did not help her identify this need. Helping teachers identify types of activities for future professional development was also not an explicit goal of the program, nor was it listed as an explicit goal for any of the programs in the research literature. Given the data from this study, I recommend that professional development programs include time to have the teachers examine the changes they have made in some detail and include in that analysis the source of motivation for those changes. This reflection might include input from support personnel and higher education faculty, and maybe even other participants in the program or teaching colleagues. This in-depth examination of positive experiences with change and the motivation behind those changes would help the teachers identify their personal trends and habits. Instead of asking teachers about their future plans as part of the program evaluation, I suggest that professional development programs help teachers identify types of experiences likely to offer the appropriate individual motivation. This would allow participants to compare future opportunities to their motivational needs, making informed choices about how to proceed.

Implications for Initial Teacher Preparation

With the goal of preparing teachers who are self-generators of change, the subprocesses in the Change Cycle and the issue of dealing with existing beliefs could and should become parts of the initial teacher preparation. Before teachers can learn how to examine their own beliefs and self-generate change, they must first examine their beliefs and make changes with guidance. The use of reflection as a means to help preservice teachers question their beliefs (Artzt & Armour-Thomas, 2002) serves as a model for initial training regarding self-generative change. Early in their first experiences in the classroom, preservice teachers should be taught to explore their beliefs about teaching mathematics and to reflect on how those beliefs align or conflict with the vision they have of themselves as teachers. Too often, this reflection is left to chance. If experiences and situations encouraging the overt exploration of one's beliefs occurred during preservice training, teachers would be better prepared for reflective practice. They would also have experience examining their beliefs, and could then move on to making this a regular part of their teaching practice.

Future Research

The first line of future research involves conducting professional development programs that explicitly incorporate the Change Cycle as the model for change. Current reform-minded programs occur on two levels. On one level, the teachers are learning about mathematics in a new way. On the second level, teachers examine the pedagogical content of the instruction. Including the Change Cycle would create a third level of awareness in these programs; an awareness on the part of individual teachers of how they are consuming and implementing new ideas. Studies examining the impact of the inclusion of this third level of knowledge must be done to determine if the inclusion requires additional time in the program.

Studies based on the Change Cycle should also examine how teachers learn to use the subprocesses in the Inquiry stage, and how they can be encouraged to transition into the mastery stage. Learning to maneuver through the vision/forethought and inquiry stages could be made more explicit in preservice courses. Studies exploring the feasibility of implementing the change cycle into preservice courses might explore the relationships between preservice teachers' beliefs and their ability to self-regulate their teaching practices. While we know a great deal about the impact of self-efficacy on a teacher's ability to implement change, teachers have not been actively encouraged to consider themselves as having moved into a mastery stage with those changes. Studies should be conducted to explore how encouragement to move into the mastery stage impacts teachers' self-efficacy for change and how that impact carries back into subsequent journeys through the vision/forethought and inquiry stages.

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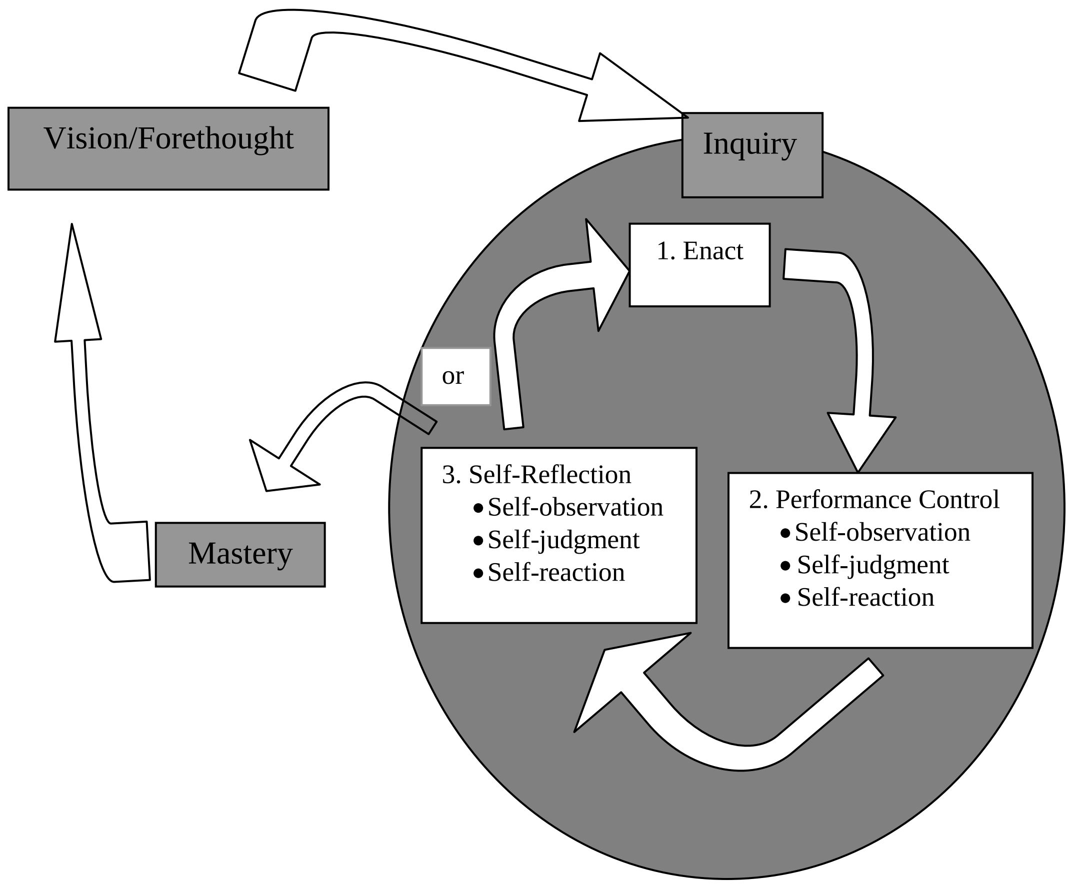
APPENDIX A

The Change Cycle



APPENDIX B

Pre-Observation Interview Script

1. Thinking about the professional development program, tell me about the big changes resulting from the program that you continue to use. How are they are working for you?

2. Were there things that you changed just a little bit?

3. Were there any changes that you maybe tried or that were suggested to you that you were just unrealistic or not appropriate for your classroom?

4. Are there any things you have been planning to try in the future?

5. Can you describe your thinking about managing discourse in your classroom?

6. What have you discovered about students understanding of mathematics?

7. What did you learn about your personal understanding of mathematics?

8. How would you describe mathematics?

9. Would you please describe your personal experience of learning about the *Standards.*
   a. What aspects made sense?
   b. What pieces of trying to implement the Standards were more complicated?

10. Thinking about yourself as a mathematics teacher at the beginning of the professional development program and now, what metaphor could you use to describe your journey over that last 3 years?

11. In the final evaluation survey, you had this to say about viewing the videotapes of each others classrooms:

    > "If you mean other teachers in the schools - no, not really. I don't think the video tapes showed as much modeling of reform minded teaching that I took anything from. Discussions are a different matter as is reading of articles.

Could you explain what you meant?

12. What experience or activity during the professional development program do you think gave you the biggest boost in your confidence to teach mathematics?

13. Was there an experience or activity that decreased your confidence in some area? Please elaborate.

14. Is there anything you wish I had asked or want to add to our conversation?

APPENDIX C

Post-Observation Protocol

The interviewer describes the Teacher Change Cycle model.

The Change Cycle Model

1) How does this model fit your experience?

2) Would you describe an example from your experience that fits the model.

3) What modifications, if any, would need to be made in the model to fit your experience?

4) What were some of the emotional aspects of changing your teaching practice?

How would you support or argue against the following statements:

5) Mathematics is connected in a linear, hierarchical manner. This influences how mathematics is learned.

6) Preparation for success in high school mathematics classes is the goal for learning mathematics in middle school.

7) Practice makes perfect.

8) Memorizing steps and procedures works for some students and does not necessarily create problems when encountering future mathematical content.

Complete the following statements.

9) My job as a mathematics teacher is to ______________.

10) When the students leave my math classroom at the end of the year, I hope they ____.

11) I think I am different from other math teachers because I ______________

APPENDIX D

Program Documents Used in Study

Data description	Lorraine	Nancy	Nicole	Jonily
Summer 2000 Bio	X	X	X	X
Summer 2000 Journal 1	X	X	X	X
Summer 2000 Journal 2	X	X	X	X
Summer 2000 Journal 3	X	X	X	X
Summer 2000 Journal 4	X	X	X	X
Autumn 2000 Bio	X	X	X	X
Autumn 2000 Journal 1	X	X	X	X
Autumn 2000 Journal 2	X	X	X	X
Autumn 2000 Journal 3	X	X	X	
Autumn 2000 Journal 4	X		X	
Autumn 2000 Journal 5	X	X	X	
Video Reflection, December, 2000	X	X	X	X
Autumn 2000 Class Evaluation	X	X	X	X
Winter 20001 Journal 1	X	X	X	
Winter 20001 Journal 2		X	X	X
Winter 20001 Journal 3	X	X	X	X
Winter 20001 Journal 4	X	X	X	X
Winter 20001 Journal 5		X	X	
Winter 20001 Journal 6	X		X	X
Winter 2001 Focus Group	X	X	X	X
Support Personnel Observation Notes January 17, 2001	X			
Support Personnel Observation Notes January 17, 2001			X	
Support Personnel Observation Notes January 22, 2001		X		

Data description	Lorraine	Nancy	Nicole	Jonily
Reflection #1	X			
Reflection, Feb 15, 2001	X			X
Video Reflection February, 22, 2001			X	X
Spring 2001 Journal 1	X	X	X	X
Spring 2001 Journal 2	X	X	X	X
Spring 2001 Journal 3	X	X	X	X
Revised Lesson Plan and Reflection February 22, and March 2, 2001	X			
Video Reflection, March 15, 2001		X	X	
Video Reflection on lesson from course content, March 15, 2001		X		
Video Reflection #1, April 26, 2001		X	X	X
Video Reflection #2, May 24, 2001	X	X		X
Summer 2001 Journal 1	X	X	X	X
Summer 2001 Journal 2	X	X	X	X
Summer 2001 Journal 3	X	X	X	X
Summer 2001 Journal 4	X	X	X	X
Video Reflection #1, October 25, 2001		X	X	
Video Reflection #2, December 6, 2001		X	X	X
Reflection #1, May 2, 2002	X	X	X	X
Reflection #2, May 16, 2002	X	X	X	X
Video Reflection, May 24, 2001			X	
June/July 2002 Final Program Evaluation	X	X	X	X

APPENDIX E

Videos for Each Participant

Nicole:

Tape #

1. October 19, 2000
2. November 15, 2000, 4/5 block
3. November 29, 2000
4. January 30, 2001, 4/5 block and January 31, 2001, 4/5 block
5. March 14, 2001, 7/8 block
6. April 10, 2001, 7/8 block
7. May 2, 2001, 7/8 block
8. May 3, 2001, 7/8 block, and May 25, 2001, 7/8 block
9. September 10, 2001, 1/2 block (1st period only)
10. October 15, 2001
11. November 18, 2001, 4/5 block
12. November 26, 2001
13. February 4, 2002
14. February 7, 2002, and April 9, 2002
15. April 16, 2002
16. April 30, 2002

Nancy:

Tape #

1. October 15, 2000, 3/5 block
2. October 24, 2000, 3/5 block (3rd period only)
3. October 24, 2000, 3/5 block (5th period only)
4. October 31, 2000, 3/5 block (3rd period only)
5. November 7, 2000, 3/5 block
6. November 14, 2000, 3/5 block, and December 12, 2000, 3/5 block
7. December 13, 2001, and January 22, 2001
8. March 28, 2001, 3/5 block, and April 4, 2001, 3/5 block
9. February 13, 2001

Nancy (continued)

10. February 27, 2001, 3/5 block
11. March 20, 2001
12. January 23, 2002, 3/5 block (5th period only)
13. February 7, 2002, 2nd period
14. February 8, 2002, 1/2 block
15. April 18, 2002, 3/5 block

Lorraine:

Tape #

1. November 15, 2000, 1/3 block (1st period only)
2. January 17, 2001, and February 15, 2001
3. March 1, 2001, 6th period
4. February 1, 2002
5. April 19, 2002, 1.3 block

Jonily:

Tape #

1. November 10, 2000, 2nd period, and November 13, 2nd period
2. November 27, 2000, 3rd period
3. December 6, 2000
4. December 11, 2000, 2nd period
5. December 14, 2000, 2nd period
6. January 22, 2001, 2nd and 3rd periods
7. March 2, 2001, 2nd period, and March 6, 2001, 2nd period
8. October 17, 2001
9. November 14, 2001
10. December 5, 2001

APPENDIX F

Timeline of Interviews and Observations

Name	Date	Description
Nicole	October 1, 2003	Observation of 1/2 block (period 2 only) and 7/8 block
	October 6, 2003	Observation of 4/5 block
	October 7, 2003	Observation of 7/8 block
	October 28, 2003	Preobservation Interview
	November 17, 2003	Observation of 1/2 block, and 4/5 block
	November 18, 2003	Observation of 1/2 block, and 4/5 block
	November 19, 2003	Observation of 1/2 block, and 4/5 block
	November 20, 2003	Observation of 1/2 block (period 2 only)
	January 14, 2004	Final Interview
Nancy	October 6, 2003	Observation of 1/3 block, 3/5 block (period 3 only) and 6/7 block
	October 30, 2003	Preobservation Interview
	November 10, 2003	Observation of 3/5 block (period 5 only), and 6/7 block
	November 11, 2003	Observation of 3/5 block
	November 12, 2003	Observation of 3/5 block (period 5 only), and 6/7 block
	January 22, 2004	Final Interview

Name	Date	Description
Lorraine	October 1, 2003	Observation of 1/3 block, 4/5 block, and 6/8 block (period 6 only)
	October 7, 2003	Observation of 4/5 block
	October 27, 2003	Preobservation Interview
	October 28, 2003	Observation of 6/8 block
	November 10, 2003	Observation of 1/3 block, 4/5 block (period 4 only)
	November 11, 2003	Observation of 4/5 block (period 4 only)
	November 12, 2003	Observation of 1/3 block, and 4/5 block (period 4 only)
	November 13, 2003	Observation of 1/3 block, and 4/5 block
	November 17, 2003	Observation of period 3 (Monday schedule)
	November 19, 2003	Observation of 1/3 block (period 3 only)
	November 20, 2003	Observation of 1/3 block, and 4/5 block
	January 22, 2004	Final Interview
Jonily	June 3, 2003	Pilot Study Interview
	September 3, 2003	Discussion with Jonily during period 2 planning time
	September 4, 2003	Observations of periods 1 and 3
	September 5, 2003	Observations of periods 3, 4, and 6
	October 23, 2003	Preobservation Interview
	November 5, 2003	Observation of periods 1, 3, 4, 6, and 8
	November 6, 2003	Observation of period 1
	November 7, 2003	Observation of periods 6 and 8
	November 11, 2003	Observation of period 8
	November 12, 2003	Observation of period 8
	December 1, 2003	Observation of period 1
	December 2, 2003	Observation of period 1
	December 3, 2003	Observation of period 1
	January 14, 2004	Final Interview