

**FACTORS AFFECTING IMPLEMENTATION OF A PERFORMANCE-BASED
MODEL IN HIGH SCHOOL MATHEMATICS:
A TEACHER CHANGE STUDY**

By

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To the Faculty of Washington State University:

The members of the Committee appointed to examine the dissertation of RUTH
ROLLINS BROCKLEBANK find it satisfactory and recommend that it be accepted.

Chair

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Abstract

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This study addressed two questions: How do teacher attributes, professional knowledge, beliefs, and skills affect implementation of performance-based mathematics instruction and assessment? How do math teachers determine whether systemic changes to performance-based teaching have been made in their practice and whether these changes have affected student performance?

Using a variety of techniques with reform-minded professionals and novices in the reform process, various factors that promoted teacher change to performance-based instruction and assessment in teaching were determined: dissatisfaction with status quo, ennui, beliefs in educational research, influence of others, and revised teaching materials. Factors that limited change were personality/teaching style connections, satisfaction with performance, distrust/disinterest in research, and challenges of change.

Teachers who incorporated performance-based teaching believed math changed with the times and all students could learn mathematics in an intellectually honest way. Whereas some teachers strictly controlled the pace and direction of classroom learning, these educators allowed students to temper both. They used a variety of educational methods and strategies—often to maintain their own interest and passion.

In general, teachers made teaching changes when teaching failed. In order to assess the effectiveness of educational practices, teachers used student responses—facial expressions, oral responses, enthusiasm, questions, written assessments, or attitudes. If their students continued enrolling in math courses and/or appreciating math, teachers considered their teaching successful. Also, teachers measured reform success by their own enthusiasm for mathematics, teaching, and learning.

Mathematics teachers who have made systemic teaching changes in their practice and theory, in collaboration with recent graduates trained in reform, have opportunities to redefine teaching and learning experiences in mathematics. Utilizing research on teacher change and its indicators, these educators have the potential for influencing reluctant teachers and learners to begin systemic change in their views of mathematics, teaching, and learning and in their teaching and learning practices. As educational progress evolves, implementation of performance-based practices provides one gauge of reform in the teaching and learning of mathematics.

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Chapter One

Introduction

During the last half of the twentieth century, high school education, in general, was criticized for

layer-cake curriculum, teacher as teller, five-step instruction in 45-minute class periods, standardized tests, isolated *egg-crate* classrooms with chalkboards and rows of desks (Romberg & Collins, 2000).

To remedy the disappointing state of the American high school experience, a variety of educational practices and theories of learning emerged. Over the last thirty years, educators and learners experienced some or all of the following: discovery learning, cooperative learning, brain-based educational theories, unlimited talents, Gardner's multiple intelligences, gifted and special education techniques, teaching with technology, whole language/whole math, peer-led instruction, and more. Sorting through the jargon, demands, and claims of each of these new educational trends was a challenge for teachers and students alike. Contrary to the expectations of some of the originators and promoters of these techniques and theories, the quality of educational performance in mathematics changed little over the last thirty years (National Research Council, 1989; Stigler & Hiebert, 1999; Wagner, 2000).

My Interest in Reform

For over thirty years I taught math in public schools in grades 6-14. Because schools usually reflect current educational philosophies, I was affected by reform in mathematics education. For example, in my early teaching years, *new math* was just reaching the classroom. Spurred by the 1957 launch of Sputnik, the new math movement created the perception that the

United States was behind in its math and science development. Because mathematicians designed much of the new math curriculum, a premium was placed on abstraction and rigor. For example, hoping the concepts would transfer, I taught students to add, subtract, multiply, and divide in base five. I taught using the method I had been taught: the presentation of an algorithm for a certain type of problem followed by a corresponding student assignment of similar problems. According to recent data from the TIMSS (Third International Mathematics and Science Study) video study, this same method is the current mode of teaching in the United States (Stigler & Hiebert, 1999).

As I worked with students, I noted many were frustrated, bored, or disinterested (often an inclusive or) with the mathematics we were studying. Also, even my most successful math students displayed a lack of understanding and/or enthusiasm. From year to year, students retained few math concepts; some of the same mathematics sixth graders learned was being re-taught, as if new, in tenth grade! I was convinced systemic change in my math teaching was needed.

As I continued teaching and participating as a member of my state math association and the National Council of Teachers of Mathematics [NCTM], I stayed abreast of math reform efforts. I learned *teaching as telling* was not the only method of teaching mathematics and began investigating other educational methods. Beginning in the 1990's, and because of my involvement in math organizations and my disenchantment with my own teaching methods, I attended conferences and workshops sponsored by NCTM and completed more mathematics classes with funding from National Science Foundation grants.

During the 1990's, I studied the tenets of reform and worked within the educational reform climate to promote systemic change. My own challenges with making significant

changes in my teaching prompted my interest in this study. Teachers who claimed it would be impossible for them to change their teaching in any significant way added motivation for my study. Their reluctance and doubt infused this inquiry with purpose.

This study chronicled several transformations. One purpose was to document the change process of the math teachers at my school, referred to as Crescent Heights High School (CHHS). The CHHS teachers were involved in a reform project with the objective of improving education for all students. The situation in which the CHHS math teachers found themselves provided both impetus and promise for inquiry about teacher change to performance-based learning and assessment in mathematics. For this study, performance-based learning and assessment required that students demonstrate an understanding of a particular concept by producing tangible evidence of their competence. The “performance” could be an oral presentation, a written explanation, a physical model, or some other form of expression. Generally, performance-based assessment allows students to demonstrate their learning in a variety of ways (Darling-Hammond & Aness, 1996; Romberg, 1992, 1995).

This study also provided information about teacher change in the context of one high school mathematics department’s change to a focus on performance-based learning and assessment. At the beginning of this study, the majority of the math teachers were unaware of reform ideas. In order for them to allow students to play a more active role in their education, the teachers were required to make changes in their educational approaches. As another wave of teachers begins to consider reform, the dynamics of change presents a new scenario. Examination of this change process supplemented current information (Kilpatrick & Silver, 2000; Kydd, Anderson & Newton, 2003; Boaler, 2000). Results of this research are relevant in today’s changing educational climate.

Research Questions

The study addressed the following questions:

1. How do teacher attributes, professional knowledge, beliefs, and skills affect implementation of a performance-based model in mathematics instruction and assessment?
2. How do teachers determine whether systemic changes to performance-based teaching have been made in their own practice and whether these changes have affected student performance?

Since studies of teacher change and performance-based learning in mathematics are limited, this research sought to provide empirical evidence on factors affecting teachers as they navigated the previously described change process. A participant-observer research model (Nolan & Meister, 2000; Ball, 2000; Amit & Fried, 2002) provided an opportunity to understand the participant and systemic context from both an insider and outsider perspective, something critical to addressing the entire scope of the research questions.

Chapter Two

Literature Review and Perspective

Changes in mathematics teaching and learning parallel research and development in disciplinary areas. For example, transformational geometry, fractals, and chaos theory have been added to recent math texts. Also, constructivist theories now appear in texts on learning theories and in professional journals. Ideas about how people learn drive many educational reform efforts. This literature review provides background information on learning theory, educational reform history, and teacher change.

Learning Theory

To both construct and support theories about the learning and teaching of mathematics, theorists must explore assumptions related to both ontology and epistemology. In this study, discussions of ontology center on the nature of mathematics—what it is and how it is communicated. Epistemology refers to the way math knowledge is generated and spread. Since a teacher's ontology and epistemology affect teaching, learning, and assessment (Romberg & Kaput, 1999; Silver, Strong & Perini, 2000; McLaughlin & Talbert, 1993), these constructs were useful in this study of the teacher change process in high school math teachers.

Ideas about the nature of mathematics and how it is disseminated are derived from general educational theories of learning. Early learning theorists are often categorized by the extent to which they agree or disagree with the ideas of rationalism, nativism, and empiricism (Hergenhahn & Olson, 1997). Advocates of rationalism believe the mind must be actively involved in the quest for knowledge. Nativists believe some important traits or attitudes are inherited; they contend knowledge is innate. Empiricists hold that sensory experience is the

basis of all knowledge. Because he believed knowing is explained as remembering the pure knowledge the soul experienced before entering the body, Plato is considered a nativist. Since Plato also believed people use their minds to learn, he is categorized as a rationalist. John Locke (1632-1704) was an influential empiricist who viewed the infant mind as a *tabula rasa*, a blank tablet, on which experience writes. As we review various educational ontologies and epistemologies, we become aware that theories build on existing ideas and that all theories owe a portion of their existence to prior learning.

Throughout the nineteenth and twentieth centuries, personalities and ideas augmented the theories of learning. Pavlov's conditioning, or reflexology, was a forerunner to the behaviorism that dominated American psychology until the early 1930's. In the last part of the nineteenth century, the establishment of national school systems and teacher preparation programs in mathematics spurred growth in educational inquiry (Kilpatrick, 1992). Educators generally agreed upon the disciplinary value of mathematics—mathematical thinking promoted certain modes of thought (Sadovnik, Cookson, & Semel, 2001).

The National Council of Teachers of Mathematics [NCTM] was formed in 1920 as a result of interest in mathematics education. World wars and technological and scientific advances accelerated interest in improving the teaching and learning of mathematics. John Dewey and others urged reform that resulted in more student-centered classrooms (Dewey, 1966). Edward L Thorndike's behaviorist psychology was the dominant instructional framework in the early part of the twentieth century (Hergenhahn & Olson, 1997). Thorndike's use of a control group in educational research legitimized this research for some doubters; it put educational research on an equal footing with other forms of research. Thorndike believed education had the possibility of changing people in a positive way; he contended scientific study

could validate this claim. Hence, the viability of educational research provided substance to education reform (Sadovnik et al., 2001).

Perhaps one of the most debated topics in the history of mathematics education is the notion of transfer (Hiebert & Carpenter, 1992), the idea that skills and ideas learned in one domain can be realized and applied in an altered or new domain. Whereas Thorndike believed in almost-automatic transfer of skills and knowledge to very similar situations, Judd studied the transfer of knowledge and abstractions from one context to another, quite different, one (Howard, 2002). Perkins and Salomon (1988) call Thorndike's "low road" and Judd's "high road" transfer. Judd (Kilpatrick, 1992) questioned the general ideas about transfer. His research argued transfer is possible on a large scale, and one must teach for transfer. Although Judd did not adequately state the conditions of transfer, his work prompted math educators to examine the relevance of math instruction (Perkins & Salomon, 1988). Bransford, Brown, & Cocking (1999) added that deliberate abstraction, which requires both motivation and deep understanding, is essential for high road transfer (Howard, 2002).

E. H. Moore's early call for unification in course work led to experimentation in the University of Chicago lab school whose faculty developed and field-tested unified courses—similar to the integrated math approaches of recent years (Kilpatrick, 1992; Osborne & Crosswhite, 1970). These courses attempted to build conceptual understanding in students—to counter fragmented approaches to math.

In the 1950's, Piaget's stages of cognitive development and associated concepts began a long line of work that would have a tremendous impact on mathematics education (DeVries, 1997; Piaget, 1970). Among other effects, his theory encouraged the use of concrete examples and physical manipulatives. Jerome Bruner made the point that readiness is primarily a function

of finding a suitable context or way of expressing the principle or concept to make it accessible to learners (Herrera & Owens, 2001). His claim that “any subject can be taught effectively in some intellectually honest form to any child at any stage of development” altered the way many theorists viewed learning (Bruner, 1960, p. 33). For example, educators and researchers began to question the effectiveness of student tracking.

Vygotsky’s assertion that education is dependent on social interaction had a profound effect on learning theories. He contended that organizational features of social interaction generate qualities of thinking (Vygotsky, 1978; van Oers, 1996). Vygotsky looked at two parts of our learning experience. He saw scientific knowledge as different from our more everyday experiences and considered education as the integration of the two varieties of learning. Vygotsky discussed an individual’s enculturation. He thought everything anyone understands internally was once learned in a physical and social setting. His *zone of proximal development* posits that some problems can be solved alone, while others involve the help of other people (Kilpatrick, 1992). Using Vygotsky’s ideas and those of anthropology, adherents to the situative perspective on learning stress the fundamentally social nature of cognition, but believe learning is tied to the situation in which it occurs (Lave, 1988). Combinations of the preceding ideas provide theoretical underpinnings for constructivist epistemologies; a discussion of constructivism follows.

Constructivist Views of Learning

Many of the above theories have collectively led to the formation of a learning philosophy commonly labeled “constructivism.” Constructivism holds that social and cultural experiences in learning are not peripheral experiences, but part of the learning package. The

various forms of constructivism all involve the idea of providing contexts and supports for students as they build understandings of various phenomena (Phillips, 2000; Ernest, 1996a).

Paul Ernest (1996a) described versions of constructivism:

1. *Information processing* is sometimes considered a simpler form of constructivism; it is based on the metaphor of mind as computer. Ernest excludes the information-processing model as a true constructivist view because some information is admitted from the outside.
2. *Weak constructivism* considers the mind as an ideal soft computer—the brain. This version accepts the traditional epistemological views of knowledge. Weak constructivism does not address the issue of the nature and status of mathematical knowledge.
3. Some learning theorists concur with von Glaserfeld that there is no so-called shared experience in learning. These *radical constructivists* believe all individuals process information differently. Hence, they adhere to the belief that individual learning is unique, and it is never possible to fully comprehend the meaning of another individual (von Glaserfeld, 1996).
4. *Social constructivism* connects individual subjects and the realm of the social. This version of constructivism holds that the mind is part of the social construction of meaning and reality is humanly constructed and constantly modified (Ernest, 1996b).

The perspective that individuals construct their own knowledge rather than absorbing it from others has radically changed views about learning (Mayer, 2001).

The idea that knowledge is socially shared and that learning may be represented as participation in social practice has brought new vigor to the educational community; it has also brought tensions, confusions, and dilemmas (Boaler, 2000, p. 2).

Understanding by Design

Conceptual understanding rather than strictly rote learning is a hallmark of the constructivist view, and has tangible manifestations in many current curricula (Northwest Regional Education Laboratory, 1998; United States Department of Education, 1995). The Understanding by Design model (Wiggins & McTighe, 1998) is not suggested as a new program to correct reform challenges, but as a “conceptual framework, design process and template, with an accompanying set of design standards” to work with reform programs. The model uses backwards design, which proceeds from the identification of desired results through the determination of acceptable evidence to the planning of learning experiences and assessment (Wiggins & McTighe, 1998). In this model, teachers look at the big picture and concepts as they design activities and assignments for their students; therefore, the model complements the performance-based and integrated math components of math reform efforts.

A major requirement of teaching using the Understanding by Design ideas is that teachers learn to employ a constructivist approach to instruction and assessment. The assessment model used in Understanding by Design is shown in Diagram 1.

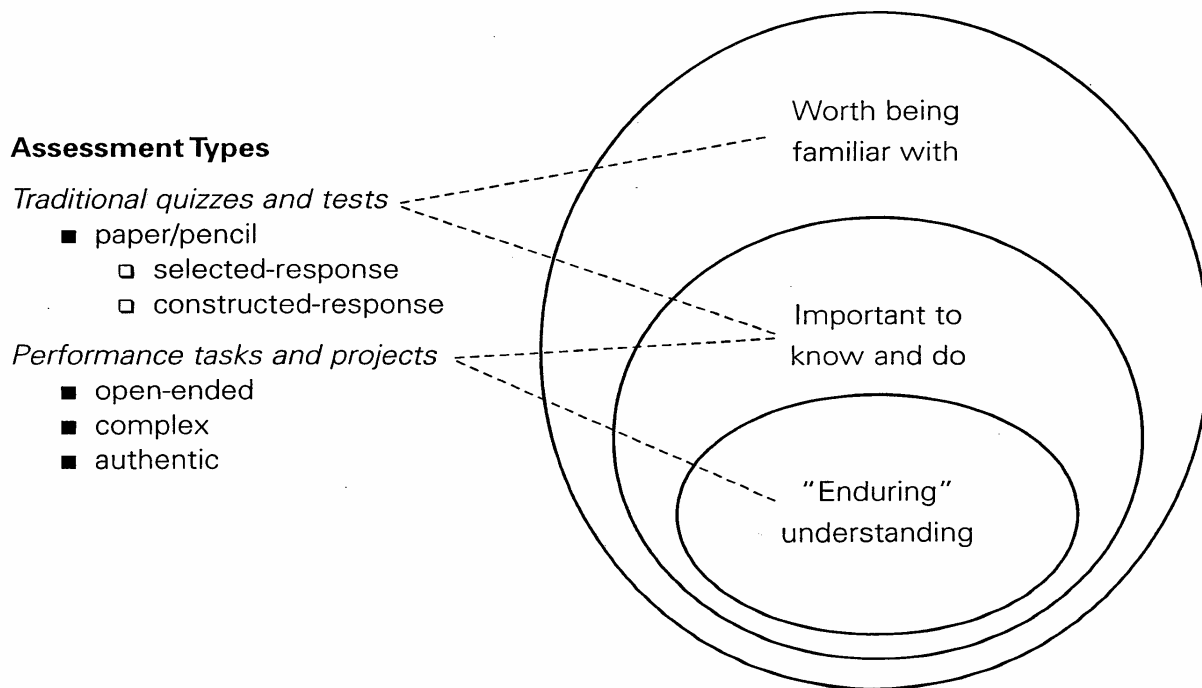


DIAGRAM 1 (From *Understanding by Design* (p. 122), by Wiggins & McTighe, 1998, Alexandria, VA: Association for Supervision and Curriculum Development. Copyright 1998 by ASCD. Reprinted with permission).

Performance tasks are performance-based assessments in the Understanding by Design model. Following a unit of instruction that uses constructivist rather than direct (didactic) teaching models that are both “engaging and effective,” students demonstrate their understanding of important ideas by completing a performance task (Wiggins & McTighe, 1998, p. 122). As described in Diagram 1, the assessment projects and tasks are open-ended, complex, and authentic.

Understanding by Design requires a more active approach to learning by both teachers and students than more direct methods. Confrey (1990) identified assumptions of both models; these views are shown in Table 1.

TABLE 1: DIRECT AND CONSTRUCTIVIST MODELS

<u>Direct Instruction</u>	<u>Constructivist</u>
1. Short student product answers are expected rather than process-oriented answers, and assessment of instruction is through homework assignments and test items.	1. Teachers build models of student understanding and gather evidence in varied ways to judge student construction of learning.
2. Teachers execute plans and routines and revising is done only if students' responses are not within the desirable limit.	2. Instruction is interactive. Teachers construct tentative paths upon which students move to construct a mathematical concept.
3. The teacher owns the responsibility for determining an adequate level of understanding.	3. The student decides on the adequacy of his/her construction.

Correspondingly, constructivist ideas altered the ways mathematical teaching and learning are viewed. Two ideas that shaped high school teaching were the perceived need for ability-tracked curriculum and the widespread belief that many students were incapable of serious academic study and had no need of it (Angus & Mirel, 1999). These ideas did much to stall the mathematical progress of many students. Performance-based teaching and assessment offered alternatives to direct instruction.

Performance-based Learning and Assessment

Historically, teachers, administrators, and parents led school reform efforts (Tyack & Cuban, 1995). Recently, educational research played a more direct, rather than evaluative, role in

molding reform efforts. Educational and cognitive researchers discussed the fact that complex social interactions in classrooms figured prominently in teaching, learning, and cognition (Goldman, 1998; Wood, 2001). Problem-based and project-based learning were usually categorized as forms of performance-based learning and assessment. Howard (2002) made a distinction between the two by noting that the goal in project-based is the outcome—the product; while the goal for problem-based is the process—the problem solving. For this study, problem-based and project-based teaching and assessment were included under the performance-based umbrella. Using performance-based techniques in mathematics transformed the class to a more lab-like classroom—with promise for increased student conceptual understanding (Lott & Souhrada, 2000).

A major factor in mathematics education reform is identifying the nature of student conceptual understanding of math (Carpenter & Lehrer, 1999; Erickson, 1998). To demonstrate conceptual understanding, students seek to understand the *big picture* and express the essentials of their learning experiences (Wiggins & McTighe, 1998; Gardner, 1999; Hiebert, 1986; Gollub, Bertenthal, Labov, & Curtis, 2002). Educational researchers and teachers now widely believe math concepts can be discussed relative to an individual learner, rather than as existing, self-described ideas (NCTM, 1989). Following the different learning theories discussed previously, conceptual understanding can be thought of in many ways, from a series of connections between ideas and contexts (Hiebert & Carpenter, 1992) to the culmination of experiences and interactions that lead to one's fluency with the content at hand (NRC, 1990).

Constructivist ideas altered the view that only certain students were capable of learning some math concepts, encouraging the key equity principle of current mathematics education reform (NCTM, 1989, 2000). In addition, as the disparity between societal needs and

mathematical study deepened, the need for reform in math education became apparent. The state of math affairs demanded the current curriculum needed “an overhaul rather than an adjustment and a revolution rather than an evolution” (Usiskin, 1985).

Ideas about who can learn mathematics and how mathematics is learned became significant. The reports *A Nation at Risk* (National Commission on Excellence in Education, 1983) and *Everybody Counts: A report to the nation on the future of mathematics education* (Mathematical Sciences Education Board, 1989) spurred reform. Partly in response to public rumblings and political outcry, NCTM became an important, organized and recognized vehicle for promoting reform in mathematics education. *NCTM Standards* (1989) quickly became a road map for the implementation of reform ideas. The essence of the reform vision of the aforementioned documents might be summarized as follows:

shifting mathematics to an engaging activity, creating and bolstering public attitudes, increasing the use of technology in problem solving, changing the focus of instruction from skills to power and shifting the focus of instruction from arbitrary rules to the science of patterns (NCTM, 1989).

Undergirded by beliefs in constructivist teaching and equity principles, the National Council of Teachers of Mathematics worked in conjunction with other important leadership groups such as the Mathematical Association of America [MAA], the Mathematical Sciences Education Board [MSEB], the National Education Association [NEA], American Educational Research Association [AERA], American Mathematical Society [AMS], representatives from business and industry, and many others to provide direction for math teaching and learning. Supported by leaders in education, business, and politics, NCTM led the charge for a more

comprehensive (systemic) reform in the teaching and learning of mathematics (Secretary's Commission on Achieving Necessary Skills [SCANS], 1991).

National support for the work of the National Council of Teachers of Mathematics provided impetus for widespread reform and research efforts. Students and educators at all levels became involved in providing vision for the required systemic reform (NCTM, 1989-2000; NRC & MSEB, 1990). A series of reform standards documents were published, digested, and modified (NCTM, 1989-2000).

Principles and Standards for School Mathematics

The reform-rallying cry in math education came from a series of government and NCTM documents. A recent reform document entitled *Principles and Standards for School Mathematics* [*PSSM*], published by NCTM in 2000, updated the recommendations from the original 1989 document that spurred much of the current reform movement in mathematics education.

PSSM has two components: principles and standards. The stated principles are: equity, curriculum, teaching, learning, assessment, and technology. These principles address the inequities that exist in math education (Kozol, 1991; Ma, 2001; NRC, 1989; MSEB, 1989; Noll, 2001). They attempt to remedy the claim that only *elite* students receive quality math education. The principles also address current educational needs of math students.

The standards are of two types: content and process. The content standards—number and operations, algebra, geometry, measurement, and data analysis and probability—express the content that all students should learn, while the process standards—problem solving, reasoning and proof, communication, connections, and representation—discuss ways of acquiring and using content knowledge.

One suggestion from the NCTM *Curriculum and Evaluation Standards for School Mathematics* (1989) was that there be a

shift in emphasis from a curriculum dominated by an emphasis on memorization of isolated facts and procedures, and proficiency with paper-pencil skills to one which emphasizes conceptual understandings, multiple representations and connections, mathematical modeling and mathematical problem solving.

The connections standard prompted conversations regarding curricular changes that more tightly integrated mathematics with other disciplines (Montana Council of Teachers of Mathematics, 1997; Spicer, 2002; Beal, Dolan, Lott, & Smith; 1990). Integrated mathematics was included in some promising programs motivated by math reform (Martin et al., 2001).

Integrated Mathematics

Numerous versions of integrated mathematics exist, but they generally consist of three or four years of instruction in algebra, geometry, logical reasoning, measurement, probability, statistics, discrete mathematics, and functions. Instead of being taught as separate topics, portions of these concepts are studied each year with much interweaving of ideas.

According to Beal et al. (1990), an integrated mathematics program for all students

- consists of topics chosen from a wide variety of mathematical fields and blends those topics to emphasize the connections and unity among those fields;
- emphasizes the relationships among topics within mathematics as well as between mathematics and other disciplines;
- each year, includes those topics at levels appropriate to students' abilities;
- is problem-centered and application-based;

- provides continual reinforcement of concepts through successively expanding treatments of those concepts; and
- makes use of appropriate technology.

Integrated math programs encourage students to work in a cooperative rather than an adversarial environment (Lott & Souhrada, 2000). Martin et al. (2001) pointed out that the NSF-supported reform projects, which include many of the more commonly used curricula and textbooks in American middle and high schools, were some of those that truly involve integrated math curricula. Researchers noted that integrated mathematics programs and performance-based learning and assessment were not mutually exclusive; in fact, performance-based techniques were cited as important to the success of integrated mathematics approaches (Lott & Souhrada, 2000; Steffe & Wiegel, 1996).

Some advantages of integrated curricula are: they build connections; make math more practical; support equity; and avoid long gaps in learning (Burkholder, 2001). Teacher testimonials regaled teacher learning, student learning, and enthusiasm that integrated math fostered (Spicer, 2002). Many integrated math programs employed current technology and interdisciplinary work—two suggested reform components (NCTM, 2000). On the other hand, integrated mathematics programs were criticized because they required: extensive teacher training in content, materials, technology, and methods; appropriate assessment measures; and non-contrived integration of disciplines—components that many argued were not inherent in the programs (McGraw, 2003).

My Involvement with Integrated Mathematics

A turning point in my teaching came in 1992 when I was asked to complete a math questionnaire as a pre-test for the SIMMS (Systemic Initiative for Montana Mathematics and

Science) Project. The SIMMS Project is an integrated math curriculum for grades 9-12 (Montana Council of Teachers of Mathematics, 1997). The survey assessed each applicant's views on the meaning of mathematics. As a result of reflecting on these questions, I had started to see mathematics as more than a set of rules, definitions, and algorithms to be memorized and reproduced. I had trouble completing the survey. I did not know the *right* answers to the survey questions and did not like that feeling. Prior math training taught me to expect *one correct answer*; however, I now believed mathematics could be described in many ways. Mathematics is a form of artistic expression; it is a system of patterns and relationships. Math is also a set of definitions, axioms, and theorems. I was frustrated over the dichotomy between the way I had been taught and had been teaching and my emerging beliefs about how students should learn and teachers should teach.

After completing further training, I joined the writing team of science and math teachers for the SIMMS Project. In this project, teachers wrote a high school integrated math curriculum with open-ended problems, cooperative learning, alternative assessments, technology, and other innovations in math education. I worked with others writing math lessons, activities, and assessments focusing on alignment with the *Standards*. I began presenting talks at math conferences.

As part of my high school teaching, I taught modules from SIMMS as supplementary units. I enjoyed the benefits provided by the reform ideas and methods and encouraged others to incorporate these ideas in their teaching. However, I found that some teachers discounted the reform movement, and I noticed I often reverted to my former *teaching as telling* methods. I became interested in teacher change.

Teacher Change

Writers, teachers, and researchers have painted pictures of teaching and reform (Joseph & Burnaford, 2001; Lightfoot, 1983; Perrone, 1985; Sarason, 2002; Schifter, 1996a, 1996b; Sizer, 1996; Cohen & Scheer, 1997; Grant, 1998). Their illustrations have provided the educational community and the general public with the triumphs, joys, sorrows, and frustrations of teaching. Because change is such a constant player in complex educational settings, educational reform and teacher change are recurring themes in the portrayals.

Teachers found any type of change in teaching methods, attitudes, or techniques challenging (Sarason, 2002). Hence, teacher change was shown to be an ambitious undertaking (Schifter & Fosnot, 1993). Teachers who attempted change became aware they received their own training and education under a system they now considered inadequate and ineffective. Hoy (2001) and Marzano (2003) reported that in order to make changes in teaching, teachers needed a desire to change as well as support of the educational community.

Incorporating principles of the Center for Collaborative Education (CCE) in New York City, Central Park East Secondary School (CPESS) is a public urban secondary school in East Harlem that has demonstrated successful change by a committed and talented faculty. The school made changes to conform to the following twelve principles of education set up by CCE:

- Schools are small and personalized in size
- A unified course of study for all students
- A focus on helping young people use their minds well
- An in-depth, intradisciplinary curriculum respectful of diversity
- Active learning with student-as-worker/student-as-citizen and teacher-as-coach
- Student evaluation by performance-based assessments

- School tone of unanxious expectation, trust, and decency
- Family involvement, trust, and respect
- Collaborative decision making and governance
- Choice
- Racial, ethnic, economic, and intellectual diversity
- Budget allocations targeting time for collective planning (Sadovnik, Cookson, & Semel, 2001).

Deborah Meier, principal of CPESS, claimed we need a new kind of teacher for schools and departments. In order for effective teacher change to occur, teachers must complete three difficult tasks: change how they view teaching and learning, develop new habits to go along with cognitive understanding, and learn new collegial and public work habits (Meier, 1992). She attributed the success of CPESS to willing teachers, parents, and students.

Teacher awareness of a realistic time frame for reform in complex educational processes allowed for measured growth with complementary individual growth and development. Ongoing monitoring of the complete change process with appropriate adjustments tweaked the overall system of change (English, Jones, Lesh, Tirosh, & Bussi, 2002).

Recent research, including that cited above, identified factors important in effective teacher change models. These models had the following characteristics:

1. Provided teachers with opportunities to build their own knowledge and understanding of teaching and learning using a well-defined image of teaching and learning.
2. Encouraged teacher participation in discourse and development of professional growth experiences.
3. Allowed that change was gradual and that educational systems resisted change.

4. Employed continuous assessment and monitoring of the change process (English et al., 2002).

Teacher Change in Mathematics

Research gives general insights that provide assistance as we view the teacher change process and its ramifications (Boaler, 2000; Bransford et al., 2000; Cobb & Bowers, 1999; Davis, 1996; Fullan & Hargreaves, 1996; Goldman, 1998; Lenker, 1998; Simon et al., 2000).

Mathematicians and math educators recognize math reform and teacher change as genuine problem scenarios. They acknowledge these challenges are in the education arena—where things are not well-defined. Math reform and teacher change legitimately constitute areas of education that pose significant real world problems for which there are no simple solutions (Polya, 1945).

Teacher change in mathematics presents challenges. Mathematics teachers face philosophical dilemmas as they attempt to reconcile content *coverage* and teaching methods (Hiebert et al., 1997). To facilitate change, math teachers need to challenge their knowledge and beliefs about teaching and mathematics (Thompson, 1992; Battista, 1994; Allexsaht-Snider & Hart, 2001). Teachers also need to investigate new information about the well-documented out-of-school, in-school math competency disparities (Bishop, Pompeu & deAbreu, 1997).

“Raised on mathematics as a body of rules, teaching as telling, and learning as memorizing, [teachers] cannot easily imagine classrooms that embody the sorts of principles and aims described in current reform documents” (Ball, 1993). Math teachers resist change even though ample evidence exists to encourage more active learning by students (Johnson, 2000; Hiebert et al., 1997; Lenker, 1998).

Many educators discount the idea that all students can learn intellectually honest mathematics. “Among many educators the belief persists that many, if not most high school students are incapable of mastering tough academic courses and need to be tracked into less challenging (but also less useful) regimens of coursework” (Angus & Mirel, 1999).

Unfortunately, the general public often holds views of mathematics and the teaching and learning of mathematics that are the antithesis of math reform. Relying on their own experiences in school, individuals still regard mathematics as a fixed and unchanging body of facts and procedures. They consider the learning of mathematics as calculating answers to set problems following specific, rehearsed techniques (National Research Council & Mathematical Sciences Education Board, 1990). As a result of their educational experiences, many adults assume educational challenges will have quick-fix solutions. Hence, part of any reform in mathematics education involves adjusting public perceptions of mathematics, education, and the change process (Thomas, 1992).

Nelson (1997) described teacher change models of the late 1980’s as expressing four different views—each with its corresponding theoretical roots:

1. Schifter and her colleagues believed in order for systemic change to occur, teachers needed to change their ideas about math teaching and learning. Using a Piagetian approach, these researchers contended that the change process involved disequilibria with the old views and reconstruction of reform views. Teachers accomplished systemic change by actually participating in exercises and activities that stimulated their own *cognitive reorganization*.
2. Carpenter, Fennema, and Peterson contended that teacher change involved change in research-based knowledge about the content and organization of children’s

- mathematical thought processes. With cognitive science as a basis for this model, teachers studied current research, involved students in problem-solving activities and used knowledge research as a framework to guide their teaching.
3. Cobb, Wood, and Yackel used social constructivism in their model. They believed as teachers and students put reform concepts and ideas into practice, teachers adjusted their beliefs about learning to conform to teacher observations.
 4. Shulman , Ball, and others argued teachers needed to adjust their own mathematical knowledge so it was more conceptual, less procedural. These researchers contended that requisite changes in teacher math knowledge allowed teachers to facilitate systemic change in math education (Nelson, 1997).

Teacher Change in Mathematics at Various Levels

Students and teachers at all educational levels are involved in the change process. Franke, Fennema, and Carpenter (1997) documented teacher change with participants in the CGI (Cognitively Guided Instruction) project. They noted four general levels could classify teacher change in the project. Teachers at Level 1 believed students needed to be shown how to solve problems; these teachers showed procedures they wanted students to use in their problem solving. Teachers at Level 2 allowed students could solve problems in a variety of ways. These teachers still “directed” the course of student solutions. Level 3 teachers fostered problem solving by carefully selecting problems. Issues other than student thinking drove the selection of problems and activities. Level 4 teachers were divided into two sublevels. The levels were determined by the differences in the ability of teachers to know their students and use this knowledge in their teaching. Teachers at the highest level consistently made use of what they knew about individual students in teaching. This well-documented and utilized program with

elementary education was one of many reform programs available in the early grades (Borko, Davinroy, Bliem, & Cumbo, 2000; Copley, 1999; Grouws & Cebulla, 2000; Lamon, 1999; Lampert & Ball, 1998).

Tsuruda (1994) and Curcio (1999) were among those who discussed reform in middle school mathematics. Tsuruda (1994) attributed the educational reform in his math teaching to an overall change in his ideas about math and math teaching and learning. Tsuruda made changes in the *spirit* of his teaching (philosophies of math, learning, and life) as well as to the *form* of his teaching (his seating charts, lesson plans, etc.). He credited his systemic change in teaching to his change in *spirit*.

Johnson (2000), McLaughlin with various other researchers (1990, 1993, 1996, 2001), and Senk and colleagues (1997, 2003) studied high school math reform. McLaughlin & Talbert (2001) described two radically different high school math departments. They claimed one school's students were hampered by the math teachers' insistence upon hierarchical subject-matter assumptions, which assigned many students to remedial courses. These researchers described the challenges to reform in mathematics:

Subject domains operate as an important context for teaching, in short, because they carry cultural mandates for teaching practice. Subject areas differ in their conception of “good” teaching and the constraints teachers perceive on their freedom to select materials, pedagogy, and instructional objectives. Math teachers, more than teachers of other academic subjects, feel constrained by canons of subject-area culture and demands for curriculum coverage. In mathematics classes, then, one would expect to see the “same” general content and pedagogy, regardless of student or organizational context, as math teachers pursue traditional norms of practice. For these reasons, mathematics

represents a “worst case” in terms of teachers’ potential openness to rethinking traditional assumptions or developing new practices to engage nontraditional students in the discipline (McLaughlin & Talbert, 2001, p. 57).

McLaughlin and Talbert (2001) posited the existence of *teacher tracking* to explain why some teachers failed to continue learning mathematics and why certain teachers were not a valued sector of mathematics departments. The hierarchy of mathematics and assignment of teachers to teaching particular courses—*teacher pecking order*—limited legitimate participation in the educational forums of some schools. Some teachers continued to have the same teaching assignments; their opportunities for personal growth and learning were curtailed.

Perhaps one of the most effective promises for the future of education in general and mathematics education in particular will be the establishment of school cultures in which learning for all participants is encouraged and facilitated (Senge et al., 2000). In order to change, teachers must have an awareness of their current teaching strengths and weaknesses and a desire to change.

Teacher Change to a Performance-Based Mode

Using the Third International Mathematics and Science Study (TIMSS) as their source of information, Schmidt, McKnight, Cogan, Jakwerth, & Houang (1999) verified the claim that what and how teachers taught was affected by subject matter beliefs and preferred pedagogical approaches. These researchers described a categorization of teachers dependent on teacher beliefs and approaches:

1. *Discipline-oriented* teachers, where discipline referred to subject matter. These teachers were more formal—rather than real-world—in their view of math and math teaching. They saw math as abstract; they believed mastering algorithms and basic

- computation was important. These teachers diminished the importance of applications, and tended to relate success in math to natural student talent.
2. *Process-oriented* teachers believed the real-world use of math was important. These teachers emphasized creativity; they thought about math more conceptually. According to this group, doing well in math was not necessarily a matter of talent. They placed less emphasis on remembering formulas, algorithms, and basic facts.
 3. *Procedure-oriented* teachers were concerned with math as a discipline that used representations of the real world. They had many characteristics in common with the discipline-oriented teachers, but gave more regard to real-world issues. This group asserted that mastering mathematics was a matter of natural talent. They wanted subject matter to be presented more conceptually. These teachers used a more formal, reception-learning, rote approach than the process group who emphasized ways of thinking.
 4. *Eclectic teachers* used a combination of the above approaches. They tended to “blend, without distinction, elements of all approaches.” These teachers were somewhat discipline, somewhat real-world oriented. In some cases, they favored more conceptual approaches. They emphasized natural talent (Schmidt et al., 1999).

Because teacher beliefs affect instructional choices, this categorization explained some teacher reluctance to incorporate performance-based techniques in their teaching.

If teachers believe that creativity is less important, or that success is strongly related to natural talent, they are more likely to create similar attitudes in their students or to spend differing amounts of time in the ways they attempt to motivate students (Schmidt et al., 1999).

Hence, group membership accounted for much of the variance in content coverage, emphasis, and other differences in teacher practices. In order to effectively incorporate performance-based work in their teaching, teachers needed to allow this approach would be beneficial to student learning. They were required to be willing to allow their attitudes about students and student learning to accept the merits of this mode of instruction.

In performance-based teaching and assessment programs, students are sometimes asked to work on projects that display their knowledge about a math topic. The model-eliciting activities discussed in *Handbook of Research Design in Mathematics and Science Education* provide examples of projects (Lesh, Hoover, Hole, Kelly, & Post, 2000). The goal of these projects was to develop activities for instruction and assessment with the following general characteristics:

- Solutions to the problems should involve important mathematical ideas. In fact, attempts were made to emphasize ten or so major ideas that the participating teachers considered to be the most important at any grade level or in any course. The goal was to focus on detailed treatments of a small number of major ideas rather than on superficial coverage of a large number of small and disconnected facts, rules, and skills. In short, the aim was to concentrate on deeper and higher order understandings of major ideas.
- It should be apparent to parents, schoolboard members, and community leaders that the tasks emphasize the kinds of problem characteristics, understandings, and abilities that are needed for success in real life situations—not just in schools.
- The tasks should help teachers to recognize and reward students with a broader range of mathematical or scientific abilities than the narrow and often low-level skills typically emphasized in traditional textbooks, teaching, and tests.

- When teachers observe their students working on such tasks and when they examine the results that their students produce, they should be able to gather useful information about their students' conceptual strengths and weaknesses, so that teaching can be more effective (Lesh et al., 1999, p. 595).

In order to effectively change to a performance-based mode of teaching and assessment, a teacher must believe it is possible to make systemic changes in teaching. Successfully selecting and incorporating performance-based work in teaching involves believing teacher change is possible and teacher change to a performance-based mode is feasible and beneficial (Thompson, 1999).

The following section documents the fact that teachers make changes in their teaching, but persistence and reflection are necessary components of change to a constructivist approach. During the last twenty years, many teachers and researchers have related stories of teacher change.

Stories of Change

Often there were differences between what teachers believed was happening in classrooms and what was actually occurring there (Tyack & Cuban, 1995; Amit & Fried, 2002). Cohen's famous study of Mrs. Oublier provided documentation of the resistance of even sincere and enthusiastic teachers to systemic change. Mrs. Oublier taught second graders and thought she had made significant changes in her teaching—from thoroughly traditional to innovative and reform-minded. Cohen found she mixed new mathematical ideas and materials with old mathematical knowledge and pedagogy; her teaching did not really show significant change (Cohen, 1990). Dapples (1994) reported that teachers who had received training in the SIMMS Project routinely underestimated the amount of *teacher talk time* in their classes. Even though

the teachers in her study had been trained in active approaches to teaching math, they did not realize they consistently talked more than students actively participated.

One of the challenges to teacher change lies in teacher working conditions. Many mathematics teachers work independently; time for discussion and collaboration are not mandated in teacher schedules (Stigler & Hiebert, 1999). In some communities, change in mathematics education is thwarted by the fact that mathematics instructors do not have the requisite training (Ma & Kishor, 1997; Stein, Silver, & Smith, 1998). In order for change to be effective, there must be constructive dialogue about educational issues in mathematics and the teaching of mathematics. Members of the collaborative groups need the prerequisite skills for the communication to be meaningful. (Kilpatrick & Silver, 2000).

Numerous anecdotal accounts of change in the teaching of mathematics documented the fact change was possible; individual stories offered glimpses of successful change components (Cohen & Scheer, 1997; Levine, 1999; Atweh & Ochoa, 2001). Lampert (2001) found as teachers made changes in their roles as instructors, they became comfortable allowing students to *wrestle* with mathematical ideas and concepts. Lamon (1999) reported that agents for change improved their listening skills; these teachers learned to listen carefully and re-phrase student questions. They re-structured their teaching to address student queries.

Lott and Souhrada (2000) noted that teachers involved in the process of change often learned to identify and concentrate on the big ideas in mathematics. Even though some teachers who were attempting change had *uneven* results in their initial attempts, these same teachers reported continuing adjustments and successes. Teachers told Dapples (1994) it was difficult to change; they found many teaching habits were firmly established and change required consistent

effort and patience. Schifter & Fosnot (1993) reported teachers involved in programs that supported reform often took risks in their teaching and learning.

Many participants realized the importance of the learning environment and made substantial changes in the educational atmosphere of their classrooms (Keogh, 2003; Wood, 2001; Bransford et al., 2000). In recent years, math educators addressed the importance of conceptual understanding and investigated programs that promoted understanding (Hiebert & Carpenter, 1992; Goldman, 1998; Wiggins & McTighe, 1998; Souhrada, 2001).

Effective-schools research encouraged more collegiality among teachers and provided models of successful schools (Sizer, 1996; Stein & Brown, 1997; Stevens, 2000). Dr. Harcombe's *Science Teaching/Science Learning: Constructivist Learning in Urban Classrooms* reported on a model professional development program in science, and the ideas are applicable and transferable to math teaching.

Harcombe (2001) delineated six elements in sustained reform:

1. Teachers' focus on student understanding, to the point of valuing student feedback as a guide for instructional decisions and redefining the learning process in terms of student conceptualizations;
2. Expansion of teachers' vision of [math] as far richer than a body of [mathematical procedures];
3. Participation by teachers as learners in a constructivist setting;
4. The security and support of a safe and nurturing peer community to offset the cognitive dissonance of change;

5. Connection to the program for a period of years for maturation of a deep paradigm shift, consolidation of new learning, and application of constructivism in the classroom; and
6. Redefinition of what it means to be a teacher who is also a lifetime learner (Harcombe, pp. 181,182).

In order to effectively incorporate performance-based materials and activities in their teaching, math teachers considered reform and embraced the change scenario. Hence, in this study of change to a performance-based model in high school mathematics, I assessed teacher willingness to make systemic change. Participating in numerous faculties, I have found that some teachers are resistant to change. Also, I have noticed that most *converted* reformers tend to revert to the teaching as telling mode in certain contexts.

Ironically, I taught for many years without doing much serious thinking about my personal philosophies of math learning and teaching. However, all teachers formulate educational theories—whether or not they are cognizant of their formulation (Sadovnik et al., 2001). My work in the SIMMS curriculum and the subsequent changes in my epistemology of learning encouraged me to investigate my own theories of learning and teaching mathematics. Since my philosophies about math teaching and learning are reflected in my approach to this research, it is important that I explain my views. These views also inform my own teaching and learning.

Chapter Three

My Philosophies of Teaching and Learning ; Change Indicators

My Philosophies

As a result of my SIMMS writing experiences, I see mathematics everywhere and in everything. In this project, writers produced investigations and projects that prompted the learning of math concepts. In seeking to find relevance in the mathematics that was taught, I learned to connect math to other disciplines. When younger, I viewed math as a system of definitions and rules, only. I have transformed my view of mathematics. A consequence of my on-going math study, teaching experiences, writing, and training is my belief that math evolves. Recent mathematics prompts new areas of interest; creativity and ingenuity are major components of mathematical insight. Because of changes in my ontology, I view math as both a science and an art. We emphasize the science part, neglecting the joy and creativity in math. In a world where so many are innumerate, I encourage enthusiasm for mathematics (Paulos, 1989, 1991). Many Americans have unpleasant associations with mathematics; I counter their negative comments.

Previously, I viewed mathematics as something that only certain people learn well; I now realize that preconceptions about math and learning stunted some learners' potentials. Many students are challenged by mathematics because they have had frustrating experiences with math in school or at home. Some students have no confidence as a result of being corrected and/or ignored. We have disenfranchised students with our grouping policies. I support the NCTM *Standards* and recognize the need for providing equity in our educational practices. At the same time, students who show special promise in mathematics should be given opportunities to enrich their studies. Teachers' feelings and beliefs about mathematics, students, and the teaching and

learning of mathematics are apparent to students. As a result of my SIMMS work, experience, and education, I have made a change in the *spirit* of my teaching—as suggested in Tsuruda’s (1994) work.

I believe in the constructivist view of learning. Every learner is unique, and yet certain commonalities enable us to be successful learners in group experiences. Math can be a social and an individual activity. However, constructivist ideas are not final educational theories and practices. We will continue to expand our philosophies of learning to include new ideas and research findings. Because of the unique qualities of learners, teachers, and contexts, we will never find one perfect ontology and epistemology.

One of my favorite teaching assignments was when I worked with sixth graders in a self-contained classroom. During those years, I mixed disciplines any time I chose. I encouraged students to use math in social studies, art, and literature lessons. From these experiences, I seek interdisciplinary learning and teaching opportunities. A well-educated person is able to adjust to a variety of situations; I assign diverse student projects and reports. I wish my teachers had asked me to complete performance-based assessments. Instead of being nudged from my comfort zone, I became adept at doing *template* math problems. I am challenged when making practical use of mathematics. Using my good memory in math studies, I failed to develop other strategies for learning mathematics. Performance-based work provides multiple ways for students to view mathematics; learning integrated mathematics requires students to extend their thinking to authentic situations.

I marvel at the problem-solving abilities of students. Some students learn best when they teach someone else. For this reason, I encourage students to share their discoveries and challenges. My experiences with problem solving mirror those reported by Chazan and Lampert

(Chazan, 2000; Lampert, 2001); listening to students and reflecting on their comments direct my teaching. Hence, my students and I learn significant math by investigating problems and their extensions. I provide learning opportunities that require students to display their mathematical knowledge. I am interested in finding out what my students understand; I seek diverse opportunities for their conveyance of ideas.

Learning is challenging. Teaching and curriculum are two of many components of education. Teachers and educational contexts are only part of the educational process. In order to understand mathematical ideas, students must contribute effort, work, and desire to the scenario. Also, learning mathematics involves knowing both concepts and procedures. Confidence in mathematics goes hand in hand with understanding. Someone who understands something can connect that learning to many other things. Williams (1998) contrasted the concept maps of calculus students and mathematicians to examine conceptual understanding of a mathematical function. These sample concept maps illustrated important information about the webbing of information and how it changed as one became more advanced in learning. Understanding mathematics involves building connected webs. There is a place for memorization in mathematics; however, understanding limits the necessity of superfluous memorization.

There are many facets and avenues for learning (Armstrong, 1998, 2003; Gardner, 1999). I rejoice in the different ways individuals view situations; however, teaching is both enriched and compounded by these differences. We learn math by doing math. It is imperative that teachers continue to learn. Knowing the mathematics a teacher studied in college is not sufficient for successful teaching in our ever-changing world. We cannot expect students to be interested in learning if we are not. I recognize and appreciate the importance of math symbols,

vocabulary and convention; we sometimes wait too long to share these with students. By modeling appropriate questioning, notation, and reflection, teachers provide expertise to student problem solving. Trusting in the abilities, desires, and talents of students allows active student participation in the process. When competent teachers and engaged students work together to learn mathematics—with each as a valued part of the endeavor—learning with understanding occurs. Being receptive to the learning process enables teachers and learners to benefit from their interaction; both experience the joy of learning.

Teacher Change Indicators

The challenges of change encourage some while frustrating others. After completing my teaching with the SIMMS Project, I retired from teaching in one state and moved to another state. I was becoming restless in my teaching, so decided to return to school for more study. I attended university classes for three years while I taught for a university mathematics department.

After these years, I accepted a teaching position at CHHS, a school that used an integrated math curriculum. I began teaching at CHHS with continued interest in math reform and systemic change. Since CHHS was working on an overall improvement process, teacher change was a necessary component of the reform movement. My interests and our school reform efforts combined to provide an environment I recognized as conducive to this teacher change study.

In defining teacher change in this study, I viewed change systemically. The indicators of teacher change to performance-based instruction followed reform recommendations in the *Standards* (NCTM, 2000), my training in SIMMS, and the relevant literature that chronicled

previous teacher change research findings. In this research, some or all of the following indicators needed to be shown in order for teacher change to be acknowledged:

1. The teacher's ontology reflected a shift in the view of mathematics to include more than the general definition of a deductive/inductive system (Chazan, 2000; Davis & Hersch, 1998; Jensen, 1998; Paulos, 1991; Romberg & Kaput, 1999; Silver et al., 2000; Harcombe, 2001).
2. The teacher's epistemology displayed familiarity with current educational philosophies (Cooney & Shealy, 1997; Lampert, 1991; Ma & Kishor, 1997; McLaughlin & Talbert, 1993; Schifter, 1996a, 1996b; Schmidt et al., 1999; Lerman, 2000; Harcombe, 2001; Simon, 1997; Thorson, 2001).
3. The teacher's practice included a variety of student assessment and assignment options (Lesh et al., 2000; Wiggins & McTighe, 1999; Romberg, 1992 & 1995; Armstrong, 1998 & 2003; Gardner, 1999; Harcombe, 2001).
4. The environment of the teacher's class provided numerous opportunities for active learning for students (Fennema, Sowder, & Carpenter, 1999; Goldman, 1998; Lerman, 2000; Hiebert & Carpenter, 1992; Schnotz, Vosniadou, & Carretero, 1999; Harcombe, 2001).
5. The teacher frequently and enthusiastically shared educational ideas and investigations with others in the department and/or school (Wiggins & McTighe, 1998; Johnson, 2000; Kydd & Newton, 2003; Lampert, 1991; Schifter, 1996; Sarason, 2002; Bransford et al., 2000; Harcombe, 2001).

6. The teacher's attitude toward student and teacher learning and teaching was positive (Levine, 1999; McLaughlin & Oberman, 1996; Torff & Sternberg, 2001; Keogh, 2003; Ma & Kishor, 1997; Harcombe, 2001).
7. The teacher showed interest in educational research about theory and practice by reading and discussing current literature on mathematics and education (Carnine & Gesten, 2000; Mayer, 2001; Wiggins & McTighe, 1998; Sowder, 2002; Harcombe, 2001).
8. The teacher displayed a profound understanding of mathematics (Usiskin, 2000; Wilson, Miller, & Yerkes, 1993; Goldsmith & Schifter, 1997; Lampert & Ball, 1998; Harcombe, 2001; Ma, 1999).

This list was not meant to be static and was modified as a result of my research findings. Also, since this study involved change to a performance-based mode in mathematics, the above-delineated indicators “drove” the teacher change to performance-based learning. In other words, because the teacher believed current educational research and was interested in making changes consistent with this research, the teacher chose to employ performance-based teaching and assessment techniques. Hence, evidence of the aforementioned indicators often prompted teacher change to a performance-based model.

Even with the best of intentions, a teacher's commitment to reform vacillates; therefore, all teacher practices showed ranges along a continuum in various categories. With this in mind, teacher change to a performance-based model was gauged by a holistic measure of practices—I looked for any indicators of change and documented them. Teacher involvement in reform efforts at CHHS made the school a promising location for research. Since the CHHS faculty and

staff selected performance-based teaching and assessment as their model, Crescent Heights High School was an ideal research site. The next chapter describes my high school.

Chapter Four

Research Site

(Note: Throughout this document and as part of the research process, teachers, administrators, schools, and students were given pseudonyms).

Crescent Heights High School

Crescent Heights High School, located in the northwestern United States, is a comprehensive four-year high school with approximately 2000 students. CHHS is in a district that includes 35 elementary schools, 6 middle schools, 5 high schools and 4 special schools. The district has an annual budget of about \$250 million. The district delights in its teaching staff; 73% of the teachers hold master's degrees or higher academic credentials. The district is fortunate to average over 100 applicants per teaching opening.

Since the last strategic plan was developed in 1999, the district noted success in the following areas: professional development, comprehensive curriculum development, and improvement in all state assessment areas. The district made use of research on best practices to encourage its teachers and administrators to implement improvement plans. In 1997 one-third of the entering ninth graders were not in the district to graduate in 2001. Also, 55% of district graduates attending state community colleges required non-credit remedial math courses. Hence, the strategic plan aimed at aligning district resources, programs, and departments to encourage high student achievement levels. The district used various statistical methods to measure success; the district and community expected documentation of improvement. CHHS was one component of the district plan.

Since the construction of CHHS in the early 60's, Crescent Heights has had a reputation for excellence. The school is located in a part of town that is usually considered an affluent

section. Over 82% of its seniors graduated following their four high school years. Approximately 88% of the students were Caucasian. The remaining students and their associated percent of the population were: 4% Asian or Pacific Island heritage; 4% African American; 2% Hispanic; and less than 2% American Indians. The majority of ESL/ELL (English as a second language/ English language learner) students were Russian-speaking. Students who used ESL/ELL services at CHHS represented 3% of the student population. Males and females were equally represented in the school. Crescent Heights' teachers, administrators, counselors, and students continuously evaluated and modified their progress and worked to maintain high status in the district (School District data, 2003).

In the year 2000, Crescent Heights High School received a five-year IMPROVE (Implementing Multiple Professional Reform Options to Validate Educational Experiences) grant to enhance the educational experiences of CHHS students. The grant was part of a \$16 million Bill and Melinda Gates Foundation grant to the school district. The majority of the work for the grant was completed during the 2001-2002, 2002-2003, and 2003-2004 school years. Teachers expected to change to more constructivist teaching and assessment strategies as part of the reform process.

In accordance with current educational research, the faculty and staff documented their changes as they attempted to move from models that used predominantly direct instruction to ones that used constructivist underpinnings. The district principals were expected to be instructional leaders—to understand this assignment as their primary role. Principal Will Corwayson supported the district goals; he served as the administrative leader at Crescent Heights for twenty years. He believed schools needed to change to meet the needs of students. In a communication with parents and students, he stated, “Our task is to provide an education for

the kind of kids we have, not the kind of kids we used to have or want to have, or the kind of kid that exists in our dreams!” In all, Corwayson worked in education for thirty-five years. During his early days at Crescent Heights, Corwayson noted that teachers stayed in their rooms and worked by themselves. He liked changes collaboration gave education and rejoiced in the progress he saw in various academic departments at the high school.

Principal Corwayson viewed change as one way to keep passion alive in education. He found educators who made changes received refreshment in their work. Corwayson believed teacher change could not be forced; he studied research findings and selected significant studies to pass on to his faculty. In order to keep teachers from being overloaded, Corwayson monitored the change process. He knew allowing gradual change with people who approved of the process was a successful way to implement change. Although some researchers claim small school communities provide a better educational climate, Corwayson maintained CHHS could achieve the same goals within its physical setting. Corwayson did not view earlier times as the “best times” but believed living in the present was the best way to live. He had great confidence in the students and teachers of CHHS. Having promoted educational reform for years, Corwayson knew teachers played important roles in educational advances (Personal interview & school documents, CHHS).

Because one of the major factors influencing reform is the teacher, teachers at CHHS were involved in the reform process. Researchers consistently reaffirmed that effective reform involved teacher input and change (English et al., 2002; Cohen & Scheer, 1997), particularly given that teachers continued to control what was taught and how textbooks and other materials were used (Parker, 2002).

Changes Supported by CHHS Teachers and Students

My first teaching year at CHHS was the second year of the IMPROVE grant; hence some preliminary records had been gathered and surveys conducted before I was hired to teach there. When students graduating from CHHS were asked for suggestions for improvement in the high school educational system, many mentioned they saw little connection between their high school learning experiences and their future plans. Students also reported they did not feel many ties to teachers or other students (CHHS *Unpublished Document*, 2000). In response to these comments and hoping to ensure continued academic excellence, the teaching and administrative team at Crescent Heights determined that “rigor, relevance, and relationships” would be the overriding themes of their educational reform efforts. In keeping with these themes, performance-based learning and assessment became a focus for CHHS beginning in the 2002-2003 school year.

The IMPROVE grant required CHHS document its reform efforts and use research as the underpinning for any change. Hence, teachers and administrators used research documents to support the acceptance of the performance-based learning and assessment model. Effective-schools research of the 1990’s was incorporated in the groundwork for reform at CHHS (Sadovnik, et al., 2001; Danielson, 2002; Preedy, Glatter, & Wise, 2003; Stone, 2002; Stronge, 2002).

Prior to implementation of the IMPROVE grant, teachers and students were surveyed about the educational environment at CHHS. Questionnaire differences that showed our school trailing the district were recorded in the following areas: activities used to develop understanding, curriculum designed for depth, focus was competence—not coverage, students

involved in exploration and research, and students presented to real audiences (CHHS *Unpublished Document*, 2000).

Based on available research and staff inservices, teachers at CHHS decided to adopt performance-based teaching and assessment as part of their reform process. Some departments at CHHS expected the transition to be easy; others anticipated adjustments that ranged from minimal to major, depending on the department. For example, the music department contended their work had always been performance-based. In contrast, some mathematics teachers expressed the opinion that there was too much to teach in mathematics to allow more performance-based work. The teachers felt pressured to complete certain prerequisites for the students to remain successful in the suggested math sequence (Romberg, 1997). Also, some math teachers indicated systemic teacher change was not possible or necessary for those who considered themselves to be teaching successfully.

As part of the IMPROVE implementation and the effective schools movement, CHHS teachers adopted the Understanding by Design model (Wiggins & McTighe, 1998). Since assessment was an essential component of the educational program, assessment models employed the constructivist view. CHHS expected to revise its teaching and assessment to incorporate suggestions of current educational research.

In my three years at CHHS, I had the opportunity to participate in and observe the change process. In the next chapter, I provide my impressions of those years. These impressions introduce the context for my study.

Chapter Five

Research Setting

During my first two teaching years at CHHS, I completed research and education courses. Because I was immersed in both teaching and taking classes, I kept anecdotal records of my educational work. I reviewed reform documents that had served as a basis for the IMPROVE grant. Realizing that I would be doing research as part of my educational program prompted me to keep records of events during my first two years at CHHS. These records provided background information for my more formal data collection during the 2003-2004 school year.

First Impressions: 2001-2002 School Year

My work on the SIMMS Project and my prior work with integrated math enhanced my qualifications for the job at CHHS. Although CHHS has an outstanding reputation in the community, my first days in the math department hinted that educational reform had not reached the department. As a colleague in the science department said, “Rocks could teach the students at this school! The only reason CHHS has such a good reputation is that the school draws students from a high SES, and many of the students would be achievers regardless of the school and its teachers.”

From my first days in the department, it was apparent a hierarchy of teachers existed in the math department. Having taught calculus or other courses in other schools did not affect one’s position. Teachers were quick to identify themselves by the courses they taught at CHHS. As a new teacher to the department, I taught three remedial classes and two “regular” classes in Integrated Math 1 courses. During an open house at CHHS, Don Blakely, an administrator, and I chatted with a parent. When Don expressed pleasure that I was teaching math at CHHS and

described some of my previous teaching and educational experiences, the parent was surprised I was teaching ninth graders, rather than older students. I replied that I considered ninth graders important and that I looked forward to working with them. Don Blakely agreed; however, it seemed parents also had a “pecking order” for math teachers.

For my first semester, I traveled to five different classrooms. The majority of math teachers kept to themselves and did not appear to share thoughts or educational activities. Four of us were hired to join the math department beginning in the fall of 2001. A few additional teachers taught miscellaneous sections of math, but including the new hires of 2001, the central core of math teachers consisted of 8 males and 4 females. Of these twelve teachers, seven had masters. All the math teachers were Caucasian with experience ranging from 2 to 38 years with a median of about 13 years. CHHS teachers are included in Appendix E, which provides information about the research participants.

As I moved from classroom to classroom, I became better acquainted with the department teachers. I learned Jim Endrew won the Christa McAuliffe teaching award for another state before moving to the district. He recently received National Board certification in mathematics. Endrew was well-versed in math reform and was interested in our math department reform efforts although he found math activities and working with math manipulatives less fulfilling than his other instructional methods.

Marie Brown was concerned with teaching effectively. She spent hours outside school time, but did not believe she had the time to implement reform and still keep up with her normal teaching demands. She was already so busy teaching that she did not think it possible to do more. Brown shared worksheets and ideas with me. She was very proficient at using the school-grading program on the computer and helped other teachers with its use. Brown was also our

representative for the state educational association and kept all teachers informed of association activities by e-mail.

Of the twelve teachers in the math department, another teacher and I expressed interest in math reform and were informed about it. Four others were ready to consider reform and had some knowledge about it. The remaining six teachers seemed to look at reform and the IMPROVE implementation as just one other thing that would interfere with their teaching practice. They appeared willing to do what was expected of them, but with no apparent interest or enthusiasm.

Since I was interested in the math reform movement and the progress of my school and my department, I wanted to be an active player in the change process. During department meetings, I expressed enthusiasm for the reform process. I shared activities and educational articles with individual teachers; some teachers used the material and appreciated it while some took the information and appeared to ignore it.

During the 2001-2002 school year and as preliminary work, I conducted a qualitative study of student perceptions of integrated mathematics at CHHS. The math department at CHHS changed to the integrated math curriculum during the 1998-1999 school year. I was interested in student thoughts about the math they were studying. I received permission from my administrators and my department head to conduct this small study. I interviewed fifteen students from 25 to 40 minutes each. The interviewed math students in the integrated study were in classes taught by other math teachers. In a math department meeting, I asked teachers if they would invite their students to participate. Most teachers told their students about the study and handed out the information. Two teachers chose not to participate. Students received a candy bar of their choice for participating.

My objective for the study was to obtain feedback from students; student reflections on our math program could prove helpful in the math department contribution to our overall reform efforts. Students were asked open-ended questions such as, “ Give two adjectives that describe your math class and explain why you chose them.” From this study, it was apparent that some changes to the math teaching at CHHS would be beneficial for students. It was also obvious that teacher perceptions of the math study at the high school and student perceptions showed discrepancies. The preliminary study suggested the math department could benefit from investigation of the change process and incorporation of successful techniques into the change scenario. Student responses about their math indicated active learning ideas were rarely employed in their classes. Most students complained about how boring and repetitive math class was; they also pointed out that the suggested activities and projects from the book were usually skipped.

The final conclusion of the study was *an integrated math book does not an integrated math program make!* As a department we discussed my findings, but most teachers did not seem interested or surprised by the results. As I became more familiar with the math teachers in my department, I realized the majority had not been involved in math reform. Two other math teachers and I belonged to NCTM; few seemed acquainted with the *Standards* and with constructivist learning theories.

During the same school year, teachers at Crescent Heights participated in a faculty inservice workshop. This True ColorsTM (True Colors Inc, 12395 Doherty Street, Riverside, CA 92503) presentation helped teachers classify their own personality and learning styles. True colors translated the four styles of Carl Jung, Katerine Briggs, Isabel Briggs-Meyers, and Dr. David Keirsey into 4 colors that matched particular characteristics. Teachers identified a

primary and secondary color to show their styles. Individuals were “structured gold students, independent green students, interactive blue students, or active orange students.” At the conclusion of the workshop, teachers with the same two colors worked in groups to present information to the rest of the faculty. Since the presentations mirrored the learning and personality styles, teachers witnessed evidence that individual differences in learners exist. By-products of this workshop were faculty enjoyment and comments resulting from the activity. Math teachers interjected comments about their “colors” in future department discussions.

Near the end of the school year, the department chair, Jeff Meadows, conducted a survey of teachers to determine teaching assignments for the next school year. Each teacher was asked to rank teaching assignments according to personal preferences; also, teachers were invited to give their views on which classes were more challenging to teach—from the standpoint of motivation. Each teacher was asked to provide personal preferences about the number of class preparations. Each was questioned about traveling from classroom to classroom. As part of preliminary information for the survey, each teacher was given an index that reflected the teacher’s current teaching assignment and the teacher’s traveling status. Those teachers who taught more remedial courses and/or regular ninth grade classes were given more points on the index. Also, teachers who traveled were given added points depending on how many rooms they moved to each day. Teachers were provided with a matrix of indices for all teachers—in order to compare assignment and travel conditions. As a reflective measure, the higher the teacher index, (supposedly) the more demanding and frustrating the teaching situation.

As a result of the surveys, Jeff discussed with the math faculty a suggestion that teachers who stayed in their own rooms be expected to teach one of the lower level courses in exchange for that luxury. Also, some teachers expressed a preference for having two preps with one being

a lower level course rather than having three preps. Incorporating teacher desires in the schedule, teaching assignments for the next school year reflected an attempt to equalize the indices. Some teachers who had taught at CHHS for a number of years believed the index idea stripped them of their seniority privileges. Others were pleased their comments about prep time and traveling were taken into consideration. Since Jeff was new to the department and the district, he facilitated the change without many complaints.

During the year, teachers Jeff Meadows and I arranged student desks into groups of three or four students in our classrooms. Some other teachers with whom we shared rooms exhibited some frustration with the added confusion that moving desks created. In most math rooms, desks were in rows. Generally, as you walked by any math room, teachers would be explaining problems and procedures either at the whiteboard or at the overhead. Occasionally, math students participated in activities and projects. At faculty meetings, comments about resistance to change in the math department were fodder for humor. The school year ended with new teaching assignments and room designations for the next year, but with few obvious teaching and learning changes in the math department.

My Second CHHS year: 2002-2003 School Year

In the 2002-2003 school year, teachers were given information about the Understanding by Design [UbD] model (Wiggins & McTighe, 1998). We met in several inservice faculty meetings in which we discussed strategies for implementing reform. With two other teachers, Jim Endrew became an Understanding by Design trainer. The math department at CHHS offered to participate fully in this training. They were the first department to have all faculty members complete the first half of the training. As a result, small groups of math teachers in the department revised several units of instruction to parallel the UbD ideas. Teachers developed

several student projects as activities to complement the instructional units, including student design and construction of parabolic hot dog cookers to assess their comprehension of the conic section work in pre-calculus.

As a department, we discussed the fact that there was usually a 12% drop in enrollment for pre-calculus class in the first semester. All recognized having students complete three years of integrated math just to have them take no math their last year or two was an unacceptable outcome. Some teachers said there was a large conceptual jump for students at this level; one of the pre-calc teachers, Patrick Clark, said the course was the first class in which students were asked to analyze and think for themselves. I countered with the idea that I hoped his comment was not true. I said I certainly hoped our students were being asked to analyze and think in all their math courses. I added that students everywhere were learning pre-calculus ideas at this stage in their math study. Finally, Jeff decided that our department would monitor class enrollments and find ways to maintain more students in the class.

A day after a district letter arrived in the community, the math teachers at CHHS had their most lively discussion. One math teacher, Sue Meyers, had a son who had discussed the letter with her. Since most teachers had not seen or heard of the letter, Sue reported about its contents and her feelings about new requirements. The district was considering changing the math requirement for graduation from CHHS to three years rather than two years. Most Crescent Heights math teachers agreed with this change, although a few said they did not know what we could teach those students who took four years to complete the required two!

Sue was pleased with the three-year requirement, but was “fired up” about the second part of the proposal—that all high school students complete Integrated Math 2. Her concern was that the department would have to change the course—water it down—to allow students to pass

the class. I was the only teacher who believed the suggestion was a valid one; I proposed we investigate and monitor our methods, assignments, and assessment without changing the “intellectually honest form” of the class (Bruner, 1960).

We decided to invite the math district supervisor to a math department meeting to discuss the issue. When Nancy Beckwith came to our meeting, she assured us the change in requirements was still being considered. She answered questions about the proposed change and informed us that the other district high school math departments were in agreement with the new requirements. After Sue Meyers and Patrick Clark challenged her remarks and claimed those who agreed with the change “don’t know what they are talking about and haven’t tried to teach Integrated 2 to all students,” Nancy replied she had not come with a target on her shirt and suggested the department communicate with the Course Requirements Committee.

After Nancy left, we had more discussion about the issue. The majority agreed with Sue, and another teacher, Drew Miller, volunteered to draft a letter to the committee. He wrote the letter, circulated it among the math teachers, and sent it to the committee. In the letter, Drew noted it would be impossible to successfully teach Integrated Math 2 material to all CHHS students.

Drew wrote that in order to comply with an Integrated Math 2 requirement teachers would have to compromise the class. The following excerpt displays the letter’s tone:

We believe the harm to our lower level students who will not receive a diploma will far outweigh the gains. We are not talking here about students who are slackers (refuse to do work, skip classes, don’t pay attention). We are talking about students who come to school and are involved in school activities. They try, they get excited when they are successful, and we try to push them to their limits. However, we feel it would be

possibly inappropriate to place these students in an Integrated 2 classroom, and say, “succeed or you don’t graduate.” (CHHS math department, May 1, 2003)

The department urged the committee to re-think its position.

In response to our letter, the co-chairs of the district Course Requirements Committee sent correspondence. Included with the response letter was a research article from The Education Trust, Inc. that reported that whether or not a student now aspired to enter a four-year college or university, all occupations that offered a family wage income now required the skills and knowledge developed in a rigorous college preparatory curriculum (Barth, 2003).

The letter concluded with the following comments:

Students do aspire to earn an income that will provide a comfortable standard of living. To assume that they will settle for less is not an option. If students dislike mathematics or find it difficult, we must embrace the challenge to change that. I encourage you to read the research and to further your understanding of the change in our society and economy. Accepting and expecting less than high expectations for each student is clearly inconsistent with the vision of our school district (District correspondence, June 13, 2003).

In response to the district decision to change the math graduation requirements to three years of math to include completion of Integrated 2, our department chair Jeff Meadows sent us an e-mail that noted:

The decision has been made. We here at CHHS are in the minority opinion. We can channel our energies into jousting at windmills (trying to convince them to change their minds) or we can focus on determining how we can make this work here at CHHS. The

principal and I agree that our efforts would be better served with the latter (CHHS Math department, 4/25/03).

Some research from the school guidance department informed us that in the graduating class of 2004, fewer than half of the students had completed Integrated 2. As shown in Table 2, the 427 current seniors showed completion of the following courses:

COURSE TITLE	NUMBER OF STUDENTS	PERCENT
AP Calc	58	13.6
Pre Calc (both semesters)	71	16.6
Pre Calc (first semester)	123	28.8
Int 3 (both semesters)	111	26.0
Int 3 (first semester)	151	35.4
Int 2 (both semesters)	194	45.4
Int 2 (first semester)	224	52.5

TABLE 2: MATH CLASSES COMPLETED BY SENIORS, SPRING 2003

As a department, we decided to focus on improving our course expectations; we needed to emphasize skills and concepts that would make our students successful. We realized we would need to work closely together to meet our shared goals.

One of the decisions of the faculty and administration was that we would implement two collaboration days—in order to build on the relationships and relevance part of our reform work. During the 2002-2003 school year, student collaboration time was scheduled each Wednesday. Teachers were required to be in their rooms to provide access time for students. Teachers

recorded the names of participating students along with the time spent in the room and the assignment completed. This information became part of the grant paper work. For the time period of February 5, 2003, through May 14, 2003, students accumulated approximately 2930 hours access time.

Thursdays were designated as teacher collaboration days—to work toward more collegiality in our staff. Some teacher collaborative days were used for departmental work; others were for IMPROVE efforts. Students participated in 3 classes out of their usual six each Wednesday and Thursday, allowing for the collaboration times. Teachers formed special interest groups for the IMPROVE grant. Meetings were held for adult advocacy, book club, national certification, project-based learning, community relations, ninth grade focus group, and study skills. For the book club, some teachers formed a reading group. I participated with the group in the discussion of *The Disciplined Mind* by Howard Gardner (1999). Henry Lloyd from the math department expressed his belief that society only needed a few mathematicians and that most students will not need much of the math that they study in their lives. He said lots of students who do not really like math should be given worksheets modeled after certain direct-instruction math books—work that was straightforward and could be completed in class. He believed some kids had so many other challenges in life that teachers should find ways for them to be successful in school. As we discussed the book, teachers mentioned a variety of epistemological and ontological perspectives. Many commented that education failed to hone in on important concepts and ideas. Students seemed to get a smattering of knowledge about lots of things. Plans for continuation of some groups were discussed. Teachers commented that they were being spread too thin with so many choices; therefore, some of the groups were eliminated. Plans for the next year included a revision in the teacher collaboration work.

As part of my participation in the reform process, I chaired an interdepartmental group that investigated performance-based learning and assessment. In June 2003, I attended a national conference on career clusters. I noticed that people across the country produced interdisciplinary lessons based on active participant learning ideas. There was reform enthusiasm that was not apparent in the CHHS Math Department.

My Third Year: The Research Year 2003-2004

A few days before school opened, our department chair Jeff Meadows invited me to participate in the interview process for hiring a person for a semester-only math position. Don Blakely, Cindy Thompson (CHHS science teacher and administrative assistant), and the two of us asked the same questions to two candidates for the position. To begin the interview, Don discussed the reputation of Crescent Heights. He stated that many people consider the school to be one for privileged students, but explained that during the preceding school year teachers, counselors, and administrators had taken a bus tour of the attendance area of the school in order to witness the diversity of socioeconomic classes represented at our school. Hence, he countered the often-expressed comment that teaching at CHHS is easy because students arrive at the school already on third base and that teachers and counselors only have to get them home. Blakeley continued by mentioning that teachers at CHHS were expected to collaborate—if you closed your door and kept to yourself in your teaching, then CHHS was not the teaching assignment for you. Blakeley also told the candidates that a charge for teachers was to develop relationships with students and other teachers in the school community. A surprising twist for me was the fact neither candidate discussed math reform efforts of the last twenty years. The more experienced candidate was hired, and I marveled at the changes in the interview process that the IMPROVE

grant had fostered. When I was interviewed, few references to reform and collaboration were made.

During our first month of school, we received an e-mail message from the principal that notified us a district administrator and he would be conducting Monthly Walk Throughs. He mentioned the two of them would be looking at four areas of interest to all of us: engagement of the learner, cognitive level, content and objectives, and context. The visitors planned to stay from 3 to 5 minutes in each classroom (District communication, 9/16/03).

A survey of the faculty and administrators of CHHS affirmed the importance of the collaborative days, so the schedule remained unchanged. Those teachers who taught the same course devoted our twice-monthly department time in math to small group meetings. Teachers who taught more than one course tried to balance the time between meetings; those who were the only ones teaching a course had the luxury of work time.

With the decision by the state that a culminating project would be required of students beginning with those who would be ninth graders in the 2004-2005 school year, our focus group on performance-based learning changed to the culminating project/focused area of study group. We spent time in our meetings setting up ideas for the incorporation of the project into CHHS education. Participants from the group grappled with the time and energy requirements the project mandated for both teachers and students.

The majority of my research was conducted during the 2003-2004 school year. The following chapter discusses the methodology employed in this research. The remaining chapters provide information about my research and findings.

Chapter Six

Methodology

Comments on Methodology

In her doctoral research at the University of Utah, Sonia S. Woodbury conducted a study entitled *The reform of practice and the practice of reforms: Teachers and change in high school mathematics*. Woodbury (2000) provided a case study of two math teachers and a principal each from two different high schools. Woodbury observed and interviewed the teachers for one complete teaching unit; therefore, she was able to write detailed accounts of their teaching and questioning methods. She told their stories in her research. Her study reaffirmed that contextual settings affect the implementation of reforms, but that teachers' knowledge and guiding beliefs drive teacher change. Woodbury also concluded that one of four teachers actually displayed the *spirit* of reform in teaching. The other three had made some adaptations in their teaching, but they had not succeeded in producing systemic reform to their work. She noted "change without difference" often occurred.

Woodbury's research related to this work; however, this study investigated the change process of a group of teachers, as well as the changes in individuals. For this research, change was acknowledged when teachers chose to make systemic changes and to use performance-based methods in their teaching. Teachers were required not only to show interest in systemic change, but also to incorporate performance-based learning and assessment ideas in their teaching. The teacher change indicators, substantiated by the literature review were provided in Chapter Three. In this study and in accordance with current research in education, multiple measures and techniques were used to assess teacher change. Hence, triangulation of results strengthened any findings that came from the study (Bogdan & Biklen, 1992; Eisner, 1998; Geertz, 1973; Glaser &

Strauss, 1967; Weiss, 1994; Wolcott, 1994, 2001). Components of the study are described in the following sections. Results from data collection over the previous two years, described in earlier sections, provided context for analysis of data and discussion of findings.

Data Collection

My data collection consisted of participant interviews, surveys, and observations along with student interviews and district statistical information. Participants included two groups. The first group consisted of CHHS teachers, administrators, and students—some recognized for their commitment to math reform. The other group was composed of reform-minded educators from other high schools and colleges, selected because they had educational records identifying them as reformers. Participants are listed in Table 3, with a detailed table provided in Appendix E.

TABLE 3: RESEARCH PARTICIPANTS

CHHS PARTICIPANTS	OTHER PARTICIPANTS
Crescent Heights math teachers whose classes were observed: Martin Compton, Marie Brown, Jill Jones, and Patrick Clark	West View math teachers whose classes were observed: Julie Munro and Amy Hansen Helenmont High School math teachers whose classes were observed: Lindsey Monesco and Kalie Ward.
Other CHHS math teachers; Jim Endrew, Dan Bennett, Jeff Meadows, Henry Lloyd, William Buck, Drew Miller, and Sue Meyers. CHHS science teacher: Cindy Thompson	Other teachers: Marie Manuel, Vicki Hemple, Seth Connelly, Angie Feltis, Nancy Beckwith, and Rita Rivera.
Administrators: Will Corwayson and Don Blakely	Nationally-recognized reform experts: Pete Sommers and Dave Winters

CHHS students: Ashley, Marty, Alek, Meredith, Charlotte, and Sam	
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Teacher Interviews

Two subsets of educators were interviewed. Math teachers and administrators from CHHS were one group; teachers and other recognized leaders in math reform were the other group. Examples of participants from the leaders group were Dr. Dave Winters, a past president of NCTM, Dr. Pete Sommers, professor and author from a prominent research university, and teachers from two neighboring high schools (West View HS and Helenmont HS) whose math departments had been involved in collaboration and reform for the last few years. Other reform leaders had served on the NCTM Board, received teaching awards, or taught workshops for leading reform groups; these educators had been involved in reform efforts for a median of 25 years. Twelve reform leaders were interviewed from July 2003 through March 2004; math teachers and administrators from CHHS were interviewed in February or March of 2004. All participation in the interviews was voluntary. The eleven other math teachers in my department were interviewed. The interviews lasted approximately an hour; they were audiotaped and transcribed. The interview questions were field-tested and adjustments made; the questions are provided in Appendix B. Participants were encouraged to provide additional comments to questions. All participants were given a consent form to sign and were told that pseudonyms would be used.

Teacher Surveys

Between August 2003 and January 2004 reform leaders completed a teacher survey—the same one that CHHS faculty completed in January of 2004; this survey is provided in Appendix A. Since attendance at IMPROVE meetings was required, there should have been about 80

respondents; however, only 40 were completed. Only four of eleven math teachers completed their surveys.

Student Interviews

In addition to the teacher interviews, students who had taken math at CHHS for at least two years were interviewed using the questions given in Appendix C. Six students were interviewed in February or March of 2004, for no more than an hour each. These interviews were in addition to the student interviews completed for the preliminary information. The interviews provided student perspectives as to whether or not changes in math teaching at CHHS had taken place during the three years of the study. Each interviewed student was given five dollars for participation.

Teacher Observations

As another part of this study, observations of each of the two “reform” math department schools (West View HS and Helenmont HS) were made during the fall semester of 2003. Two teachers from each school were observed. A record of each observation was made, using the form provided in Appendix D. Each teacher was observed on two different days. I spent two days at West View observing two teachers each day, and two days at Helenmont observing two teachers each day. The days were not consecutive, but were in the middle of the week on various weeks. Classes were observed on Tuesdays, Wednesdays, or Thursdays so that finding a substitute for my classes was not a problem.

Also, four math teachers at CHHS were selected and their classes observed. I chose teachers willing to participate who represented what I perceived to be various levels of interest in participation in reform. In order to have some comparison data, I observed a total of ten classes in disciplines other than mathematics; four of these were at CHHS, the others at West View and

Helenmont. Notes of observations were recorded using Appendix D. An area of interest in the observations was whether teachers incorporated active learning components in methodology in their classrooms. Also, evidence of teaching for understanding was noted.

Analysis

In analyzing student, teacher, and reformer data, I sought information that related to my research questions. Because I had never worked closely with the participants, my analysis was based on their written and stated comments. After transcribing interviews, I read through each one, highlighted, and color-coded any words or phrases that related to my two research questions. I wrote the words and phrases on post-it notes and arranged the notes in groups. I also compared groups and looked for any connections or ties across them. I assumed there would be differences in teacher responses to the questions about change from the two groups. I also anticipated that responses to the questions about ontology and epistemology would provide some variety. In organizing the post-it notes, I used color of note and color of writing on the note as ways of differentiating between CHHS teacher responses and those of other teachers. I used the developing themes to measure teacher change according to the specified indicators.

Survey Analysis

I had planned to analyze the surveys using appropriate t tests; however, the number of respondents eliminated that possibility. Due to the limited number of completed surveys, I decided to use the surveys descriptively. I gathered information about reform leader surveys and the surveys of CHHS teachers. I contrasted the surveys of other teachers at CHHS with those of the CHHS math teachers. I looked for common themes in the comment sections of the surveys. Comparisons between the responses of reform leaders, CHHS teachers, and CHHS math teachers provided information about reform. Because most reform leaders had been

involved in teacher change to a constructivist model for at least ten years, these comparisons provided insights into the change process. Using the interviews and surveys, I sought any differences between teachers who embraced reform and those who were unaware of reform or avoided it. I also looked for any commonalities among responses to various questions. With each question, I considered the teacher change criteria delineated in Chapter Three under the heading *Teacher Change Indicators*; any comments that gave information that related to those criteria were carefully noted.

Classroom Observation Analysis

Analysis of classroom observations was made using the Appendix D form. Anecdotal comments were written to document teaching for understanding ideas. Maps of classrooms substantiated additional information about classroom work. As I observed classes, I looked for evidence of student participation. I kept a written record of the questions and responses that were given. I also documented any work that was conceptual in nature.

Analysis of Student Interviews

Student interviews were audiotaped and transcribed. Analysis of these interviews was made in a method similar to analysis of the teacher and reform leader interviews. Using the indicators of teacher change, I color-coded and organized comments following themes related to my two research questions. After listening to comments from a few students, I noted many similarities in student responses. When I felt I was obtaining no further information, I stopped interviewing students. School documents and grant records provided documentation of testing and reform attempts. Sources of data were the surveys and interviews, along with documents, test scores, and achievement records.

In each type of analysis, I color-coded and organized comments following themes related to my two research questions. The teacher change indicators given in Chapter Three were used to determine change:

1. Teacher's ontology reflected an enlargement of the view of mathematics.
2. Teacher's epistemology displayed familiarity with current educational philosophies.
3. Teacher's practice included a variety of assessment and assignment options.
4. Environment of the teacher's class provided opportunities for active student learning.
5. Teacher shared educational ideas and investigations with others.
6. Teacher's attitude toward student learning and teaching was positive.
7. Teacher showed interest in educational research about theory and practice.
8. Teacher displayed a profound understanding of mathematics.

When designing the interview and survey questions, particular items were selected because they related to the first or second research question. An overview of the analysis of this study is provided in Table 4.

TABLE 4: OVERVIEW OF ANALYSIS

RESEARCH QUESTION	CTS	OPS	CTI	OPI	SI	O
1. How do teacher attributes, professional knowledge, beliefs, and skills affect implementation of a performance-based model of instruction and assessment in mathematics?	X	X	1,2,4-9	1,2,4-9	3-9	X
2. How do teachers determine whether systemic changes to teaching have been made in their own practice and whether these changes have affected student performance?	X	X	3	3	2-7	X

<p>Key:</p> <p>CTS: CHHS teacher survey Question numbers are indicated where appropriate; X in column means some insight was gained in these areas.</p> <p>OPS: other participant survey</p> <p>CTI: CHHS teacher interview</p> <p>OPI: other participant interview</p> <p>SI: student interview</p> <p>O: observation</p>

Limitations

Learning theorists have utilized the work of previous researchers to make clear the fact that students are no longer considered to be *tabula rasa*—blank slates—upon which teachers can imprint information. Rarely do today’s researchers state theories of learning that dismiss students as insignificant in the educational environment. Constructivist ideas of learning play a part in current educational theories (Ernest, 1996; Fennema & Romberg, 1999; Goldman, 1998).

In a similar fashion, educators cannot be considered *tabula rasa*—blank slates (Cooney, 2003; Lieberman & Miller, 2001). Often, teachers play a key role in research studies and educational advancements. Participant-observer research implies both familiarity and complexity—the researcher must balance the conveniences and passion for educational

experiments with the requirements for research. In order to conduct research, a researcher needs to delineate biases and clearly assess complications to any study. After over thirty years as an educator, I contend I cannot be objective in this study. I attempted to identify biases and restrain those I could; I articulated my other biases. With my experience and training, I was in a unique position to conduct a study of teacher change to a performance-based model in mathematics. The fact that many CHHS math teachers were novices to math education reform provided enhancement.

My interest in teacher change and performance-based learning and assessment is a result of my training and experimentation with integrated mathematics and the change process. I am an advocate of the NCTM *Standards* and encourage others to accept educational suggestions that promote individualization of learning and assessment. Having taught for over thirty years, I am also a realist. I realize many ideas that seem perfect in an isolated graduate course or text become unmanageable in a typical high school math classroom with 25 to 30 students of varying abilities and interests. Because participation in the interview process was completely voluntary, I did not know how responsive the members of my math department would be. Some math teachers at CHHS were beginning to show interest in reform work; others seemed unmoved. The fact some teachers might not have been interested in participating affected the findings.

Many factors influenced teacher change at CHHS; hence, my findings are representative of a sector of the reform process. In this study, no attempt was made to attribute the implementation of teacher change to performance-based instruction in mathematics solely to the efforts of the math department and teachers. Although math teachers were the major players, all teachers at CHHS were involved in educational reform. Also, because changes to performance-based instruction were entwined with overall changes to constructivist approaches, assessment of

changes to performance-based efforts were complicated. In determining whether or not teachers had implemented performance-based work in their teaching, a holistic assessment was made using available surveys, interviews, and observations. For teachers who were not observed, self-assessment and reputation in the teaching community provided evidence, although some self-assessments were not consistent with my records. These anomalies will be discussed in later sections. Throughout this research, I showed professional attitudes toward involved teachers, leaders, and students. I kept in mind that my enthusiasm for reform could hamper this study.

Delimitations

Since this study involved documentation of the reform process in individuals for a given math department, conclusions from the study were not intended to be generalized.

Preview of Next Three Chapters

The next chapter presents snapshots of four math teachers—one from West View, one from Helenmont, and two from my school, CHHS. The descriptions of these teachers provide background information for discussion of the research questions in Chapters Eight and Nine. Chapter Eight explores the factors that influence teacher change to a performance-based model in mathematics, while Chapter Nine views teacher perceptions of their teaching changes.

Chapter Seven

A Tale of Four Teachers

As part of our IMPROVE work, I petitioned the performance-based focus group for funds to visit two high schools in our district. Our math specialist Nancy Beckwith had suggested these math departments as ones whose teachers incorporated performance-based techniques in their math teaching. The group granted me funds to employ a substitute for four different days in order to visit West View and Helenmont High Schools. The visits, along with surveys and interviews of the teachers, offered me glimpses of the math programs at the two district schools.

Because the department chair, the grant coordinator, and other district teachers had recommended them as teachers who advocated reform math ideas and had made systemic changes in their teaching, two particular teachers from West View and two from Helenmont were selected. Since these teachers were noted as change agents—teachers who advocated and supported change—at their schools, their insights into the change process in high school math teaching would be helpful. Although two teachers from each of these schools were observed, interviewed, and surveyed, a snapshot of only one of the teachers from each school is presented. In my opinion, one teacher exemplified more indicators for systemic teacher change than the other teacher; hence, this teacher was highlighted. Each selected teacher’s complete name is provided in introductory material; however, only the teacher’s last name will be used for the remaining portion of each narrative. The first teacher discussed taught at West View High School.

West View High School

West View High School had about 1500 students of whom 52% were males. While the number of students who qualified for free or reduced-price meals at CHHS was about 20%, 41%

of the students at West View qualified. About 87% of the students at West View were White with the other students having the following ethnicities: 5 % American Indian, 2 % Asian or Pacific Islander, 3 % Black, and 3 % Hispanic. 83% of the students who began their freshman year at West View graduated from the school. Sixty-eight percent of the sophomores passed the state-mandated test for reading, while forty-eight percent passed the math portion of the exam. One of the math teachers who fostered reform in the department was Julie Munro.

Julie Munro.

Having worked as an accountant for a number of years, Julie Munro returned to school at twenty-six to earn a second bachelor's degree. She found her accounting job to be "mind-numbing." After helping a friend with a math class during her lunch break, Munro realized her true love was mathematics. During her 14 years of teaching, Munro made changes in her teaching in response to dissatisfaction she felt in her work. In describing her early teaching years, Munro said she would hang onto the podium, talk to the kids, and have them answer questions. Because she had learned easily with traditional methods, it took Munro a few years to consider other teaching approaches. In visiting with students and adults, Munro saw the frustration some people experience in mathematics. To remedy apparent student boredom and failure, Munro opted to pursue other teaching approaches.

For a few years, a colleague and she taught in adjoining rooms. In collaboration with this colleague, Munro selected problems that addressed the main concepts she was teaching. Working together, they reflected on their teaching and came up with projects and activities that seemed to work well with their students. They often commented, "Why didn't we figure this out a long time ago." Munro and her friend felt their collaboration made reform work for them. Because of budget and space constraints, they were moved to separate parts of the building; their

supplies and equipment broken up. Munro missed the camaraderie. She believed her teaching suffered from the scarcity of quality reflection time she had with her colleagues.

Since using techniques that involved more active student participation, Munro did not have as many student questions about why they were doing certain assignments. Munro enjoyed watching her students work together to solve problems and complete projects. She liked listening to student conversations as they discussed their work; she believed students learned by talking about their work. To illustrate how this might look in her classroom, I will describe one of Munro's favorite projects, a textbook activity revised by the math teachers. Students were given a certain base from which they were to plan and construct either a prism or a pyramid, with more points given for the pyramid. The object was required to have a certain surface area; the volume was then calculated. Finally, students built a physical model of their prism or pyramid. Students worked on this project in pairs; they asked questions as they worked and revised their plans as they went. After a teacher revision, the project was changed so that students built a small net of the object and then used a given scale factor to make it a prescribed size. According to Munro, students learned "a ton of math" by completing this assignment.

Munro appreciated it when a group of teachers designed a project because they created the assessment rubric at the same time. She explained it was important for all involved teachers to participate in designing projects by sharing the following story. After a group of teachers had worked diligently on a project, another teacher who was too busy to attend the meetings tried to use the materials. That teacher had the project "fall flat on its face" because the teacher hadn't been in on the discussions and misused the materials. Hence, if a teacher was not engaged in the development of a project, that teacher did not work as effectively with the materials.

When I observed Munro's class, it was apparent the students in the group were some who lacked motivation. Many of her students had unusual piercings, hair colorings, tattoos, clothes, and attitudes. Several students listened to headphones while they were working, although they removed the earplugs when they communicated with Munro. Students sat in rows, but were urged to work with others. Munro walked down the rows, encouraging her students to work, giving them suggestions, and then adding "Okay, are you good to go?" It was obvious Munro had built rapport with her group of what some would call "disenfranchised" students.

Students from another of her classes were self-motivated; she turned them loose on a project that they worked on during the class period. Once Munro had given them an assignment to design a poster that presented the important ideas from the current chapter, the students worked in groups with appropriate discussion and engagement.

Munro lamented the fact she did not have sufficient time to evaluate whether she was doing any good. Munro went by her "gut feelings" about the students and their positive attitudes about class and work. Because she believed students understood their work, she hoped the state-mandated tests would show the results of her labors. Munro said her teaching had changed systemically over the last ten years. She credited studying current educational research and working with colleagues as the major factors that helped her revise her teaching. After teaching for fourteen years, Munro believed teachers needed to let students learn by doing—not by listening to an explanation. In earlier years, Munro *presented* the material and then her students did their assignments. Gradually, she changed her view of teaching until she saw the teacher's primary role as someone who asked appropriate questions and motivated students. As a result, she gave her students a problem and saw what they could do with it. If she was tired, she felt that she was doing too much of the work. She believed students were the ones who should be

working. Munro changed to a performance-based model; she planned to keep assessing her teaching and refining her change process (Munro, West View HS, 14 years, personal interview and survey, 7/31/03; observations, 12/9/03 & 1/6/04).

Helenmont High School

The second teacher, Lindsey Monesco, worked at Helenmont High, another secondary school in the same district as Crescent Height. With over 1600 students, Helenmont High School had an 86% graduation rate. The school population was 91 % Caucasian, 2% American Indian, 3% Pacific Islander or Asian, 2% Black, and 2% Hispanic. According to district records, 23% of the students received free or reduced-price meals. While 74% of CHHS students passed the state-mandated test in reading and 52% met the standards in math, Helenmont had corresponding passing rates of 66% and 51%.

The math department at Helenmont consisted of ten teachers who spent extra time and resources to ensure the success of their students. One of the first teachers with whom I visited commented on the exceptional quality of the math department. In her first year of teaching at Helenmont, she said, “It’s amazing how just after we completed a unit of study, the teachers got together and discussed what could have been better. They were always trying to improve their teaching and share ideas with each other.” A mentor of this group of teachers was Lindsey Monesco.

Lindsey Monesco.

Monesco had a master’s degree in education and had taught mathematics for twenty-one years. Monesco believed students learned by being actively engaged in the process. She said, “If you ever think you know everything about teaching, it’s time to quit!” Monesco described

mathematics as “challenging, beautiful, useful, interesting, and fun.” Each day she strove to be a better teacher. She felt the most important requirements for teachers were:

1. Believe that students—not mathematics—are the center of our work.
2. Love mathematics and understand your subject.
3. Facilitate lessons so the student is actively engaged and doing the thinking.
4. Have a toolbox of strategies to help all learners (Monesco, personal interview & survey, 3/22/04).

Monesco was a professional. She stayed current on math and educational research; she believed that exploring many avenues of instruction was an essential part of teaching. During class observation, Monesco made efficient use of class time and resources. While she discussed finances and choices with the class, one student ran the display device for the calculator and showed the selected options. Students were introduced to a “Choose your Future” project aimed at forcing economic decisions and consequences. Monesco deftly worked the overhead and a Power Point demonstration of financial ideas. She presented various money scenarios and related a few personal experiences. Then students were given an assignment in which they had to select future financial options and justify their selections. Students used written explanations, graphs, and statistics to substantiate their choices.

In different corners of the classroom, many display boards and posters showed student work from another class that had studied quadratic functions. The students were given an assignment to create a fountain display with advertising to convince a certain company that their proposal was the best. Students presented graphs and statistics about the fountains. They determined the angle and velocity of each water spray; they verified their work with appropriate mathematical support. Monesco taught students in her classes to use TI-Interactive and other

computer programs to present their data and arguments; these programs were used in the displays. Students sat in rows, but moved to work together during major portions of the class period. Before I left the classroom, Monesco gave me six projects she had effectively used. She said she revised the projects each year; she also wrote new exams each year. Monesco believed it was imperative that teachers adapt to the current educational climate. She expected her students to give effort in their math work commensurate with the effort she made to stay abreast of educational developments. Monesco considered change an essential element of her teaching.

In order to study for their final exam, students were allowed to take all exams home. Designing new exams each year eliminated any problems that resulted from students' keeping their exams. Monesco asked that I send any materials that I enjoyed using to her. She noted that creating good projects and activities was a challenging element of performance-based work. Monesco enjoyed working with others; she benefited from community reflection on teaching practices. During my visits, Monesco checked with other teachers on some activities they had planned. Her willingness to share materials with me made it evident Monesco collaborated with others on a regular basis (Monesco, Helenmont, 20 years, personal interview and survey, 3/22/04 and observations 12/10/03 & 12/14/04).

In the next segment, two math teachers from CHHS are introduced. These teachers and their thoughts about reform help inform us about the educational climate in the math department at CHHS.

Two Crescent Heights Math Teachers

The next two teachers teach at my school, CHHS. Five of the twelve teachers have master's degrees in mathematics; all of the teachers have secondary math credentials. Math teachers at CHHS noted the excellence of the group, especially the diverse talents and abilities

that existed among them. Finding time to interview all math teachers at CHHS was challenging. Many math teachers arrived at 7:30 and left at 3; adjusting schedules in order to visit with them outside working hours took considerable planning. When asked for an interview, teachers gave responses ranging from excitement and encouragement to hesitancy and bewilderment.

I interviewed each math teacher at CHHS and I observed the classes of four teachers: Martin Compton, Marie Brown, Jill Jones, and Patrick Clark because they represented what I considered to be varying views about reform. None of the four was involved in systemic change, although Marie Brown expressed interest in incorporating the *Standards* in her teaching. Each of these teachers had taught math at CHHS for over ten years. Each had taught courses from slow-paced Integrated Math 1 through Integrated Math 3. From the four teachers who were observed, two were selected for the following snapshots. These two were highlighted because in considering their interest in reform, they expressed contrasting views. Also, I viewed them as *major players* in the success or failure of the reform efforts in the math department at CHHS; hence, these particular two were chosen.

Marie Brown.

The first teacher, Marie Brown, expressed interest in reform, but stated she could not fit it in her schedule. Brown was energetic and enthusiastic and had taught for about twenty years; she had a break in her teaching years to raise her daughter. Brown had taught at CHHS for the last twelve years. She was frustrated by the demands made on teachers and wondered how teachers could do it all. Her students said she made class fun even though when she looked out in the room, “They don’t seem like they are having fun—I can’t usually tell that they think I am funny.”

In Brown's early teaching, she did not remember ever calling parents. "Kids were well-behaved and did what they were asked." She said she followed the book and did not remember anyone telling her what she was supposed to do. "It was easy—the old style—I'll tell you what to do and you do it." She thought her teaching had not changed much. She usually lectured and gave notes for the majority of class time. Brown had some reservations about making systemic changes in her teaching. Because it took longer when students did things, Brown did not involve them as much as she felt she should. Brown knew she explained math well and did not want to waste time with other methods, just in case they were not as effective. In general, there was a math topic, she told the students about it, the class discussed it to get an understanding, and then the students practiced by completing an assignment. Brown was reading *The Teaching Gap* (Stigler & Hiebert, 1999) and identified her teaching as the method being criticized.

Brown believed students needed to learn how to explain math to others. From recent reading, she knew pupils should be talking more about math and working in groups. Brown believed she should involve students more in the process, because "my teaching is not getting to the kids as well as it should." She did not understand how to do everything; she knew the traditional way she was taught worked for her own learning. Brown wondered when other teachers said *they* talked in class whether the teacher was talking or whether *they*, the students, were actually talking. Brown worried she would not have time to do everything. She knew it took longer to get students to respond, than to just tell them. In her recent reading, she was studying constructivist views.

In observing Brown, I witnessed her energy and enthusiasm. It was apparent that she gave time and thought to her lesson preparation. She assessed student understanding by correcting four-problem reviews weekly; she also used notebook quizzes as a way of rewarding students for

taking accurate notes. Because Brown liked to work at home where she could be comfortable and spread her work out on a big table, she often took work home to correct. Brown felt her teaching was effective—but recognized it as being *old school*. Her reluctance to try new approaches that gave students more active roles in their learning and assessment stemmed from the confidence she had in her own efficiency. Being organized and making use of every minute of class, Brown was not convinced that incorporation of constructivist teaching and learning strategies would improve her teaching enough to make it worth her effort. Brown did not trust the abilities, judgments, and instincts of her students enough to allow them more input in the educational process. However, the fact Brown, an NCTM member, read math journals and expressed interest in math reform and performance-based instruction indicated she might begin dabbling in the change process (Brown, CHHS, 20 years, personal interview, 3/2/04, observations, 2/10/04 & 3/10/04).

Patrick Clark.

A second CHHS math teacher who offered insight into the math department and reform was Patrick Clark. After working in business for fourteen years, Patrick Clark decided to teach mathematics so he would have summers off. After teaching four years, he decided having summers off was not a good enough reason to stay in teaching. He decided to remain teaching so he could help young people learn to think. He has been teaching for twenty years.

Clark liked to teach by asking questions. He said, “I have the ability to ask students the same questions back—in other words, I listen to hear what the lack of understanding is and ask a question that pulls those ideas out.” Clark thought his own experiences as a student affected his teaching negatively. He explained that he liked being a student; he enjoyed learning in or outside of a classroom. He assumed his students were just as excited about learning. It was

difficult for Clark when some of his students “were not at all interested in learning.” He called that fact “the great tragedy—their not being interested in learning at all.” Clark said that often times his clashes with students were a result of his failing to see their *distress* and their failing to see his *excitement* in learning. He stated his biggest drawback as a teacher was that he had “a difficult time recognizing that some people just don’t want to learn anything.”

Clark did not plan to make changes in his teaching, but for different reasons. Clark felt no pressure to change his teaching. In fact, he said the state standards were becoming “more in line with what I have always tried to do.” Clark made changes in his teaching when he believed he had failed. He changed his teaching when he did not see students learning what he wanted them to learn; he told students he wanted them to learn to think. He was very results-oriented. Clark wanted evidence his students were learning to be critical thinkers. By this he meant that his students expressed opinions during the math discussions, responded to his queries with suggestions and hypotheses, and followed the conceptual development that he presented. He explained the kind of thinking he expected as he conducted lessons with his students. During a lesson on arc length and sector area, a student said, “When the angle changes, then the arc length changes so I think arc length depends on angle.” Clark continued by asking, “Is it correct to say that arc length depends on angle?” His students and he discussed this idea. In another exchange, Clark asked students, “Define a slice of pizza for me.” One student replied, “It’s almost like a triangle except it has arc length for one side.” “Beautiful!” returned Clark. During another classroom exchange, Clark asked students how much of a circle 45 degrees represented. Courtney answered, “one-eighth of a circle” to which Clark responded, “Courtney knows fractions. Most adults wouldn’t know a 45-degree sector. Of course, it isn’t relevant. That’s why we call it math!” At the end of the lesson, Clark asked, “Why don’t they make pizzas

square?” When no one responded, he added, “Because then you wouldn’t be able to do these problems!”

Clark used projects with older students because he received acceptable results with them. He liked the ball bounce activity from the Integrated 1 text because the results gave a reasonable model of direct variation. In this activity, students worked in groups of three or four to investigate the relationship between drop height d and bounce height b for a variety of types of balls. The students recorded drop and bounce heights for various balls, using mean bounce height from four entries for each drop height. In exploring how the bounce height related to the drop height of the balls, students received a model of direct variation with constant $\frac{b}{d}$ (Rubenstein et al., 1998, p. 367). Even though he enjoyed this activity, Clark was not convinced after his students had completed the exploration; they really understood direct variation. He noted the challenge with using performance-based techniques was in finding or producing meaningful activities and projects.

When Clark taught, he used questioning strategies to conduct the day’s lesson. Clark asked students questions until he was satisfied that they understood. Most of the class time was used in developing the concepts of the day. Clark directed the questioning and responded to student questions. He used Socratic methods to push the students to think about the concepts. Although he sought good projects, Clark was not interested in making significant changes to his teaching. He was pleased with his teaching; he wondered why more teachers did not strive to enhance student understanding in their work. Clark demanded quality work from his students—both in their written work and in their class participation. For the first assignment of each semester, he set the standard for written work by assessing each paper on a five-point scale, with five being ideal. The grade for this paper was not used for the grade average of any student, but

it provided students with a gauge of Clark's expectations. Before completing the assignment, students knew that the work would be used in this way. Clark provided this student opportunity in order to set his expectations for the year.

Clark admonished students to be sure they were asking conceptual-type questions. He refused to answer the "how do you do problem 26-type" questions. Although Clark believed that students came to appreciate his demands for clear thinking and exact communication, his methods intimidated and alienated some students. Clark constantly extolled conceptual understanding; however, his method of assuring student understanding was dependent on his thinking, planning, and adjusting. Clark drove all learning with his questions and responses. He did not display trust in student planning and lesson implementation.

In discussing constructivism, a perspective Clark had not studied, he agreed communication was extremely important in learning mathematics. He contended if you can't explain a concept to someone else, then you really don't understand the idea. Clark believed his methods were successful; he produced a good product (Clark, CHHS, 20 years, personal interview, 2/24/04, observations, 1/12 / 04 & 1/26 / 04).

Case Study Discussion

The preceding four teacher snapshots suggested some factors that promoted or deterred teacher change to performance-based work in mathematics. Teacher sentiments about their day-to-day work and teacher observations provided some familiarity with their math teaching. Also, teachers discussed their beliefs about mathematics and assessment. Because teacher change is driven by all the aforementioned factors, becoming acquainted with the teachers was important. Since the propensity to change to performance-based teaching can go from near zero to near one with dynamic humans, I recognized a teacher could exhibit proclivities to change that varied

with activity, time, and context. Hence, teachers who were immersed in reform also talked about the challenges and negatives associated with change to performance-based work. The four teacher tales preview the research question findings that are discussed in Chapters Eight and Nine. Chapter Eight discusses the first research question, which can be considered in three components:

1. How do teacher attributes, professional knowledge, and skills support change to a performance-based model of instruction and assessment in mathematics?
2. How do these factors limit a teacher's ability to change to a performance-based instructional approach?
3. How do teacher beliefs about math and math teaching affect the change process?

Chapter Eight

Change to Performance-Based Instruction

In surveying and interviewing teachers, I learned there were many prompts that encouraged teachers to revise their math teaching. Secondly, there were factors that limited teacher ability to make changes to performance-based instruction. Also, teacher ontology and epistemology affected the change process. In this chapter, I present findings based on an analysis of thirty-two teachers, administrators, and students. Using thematic analysis, I determined specific factors that were important in order for teachers to move toward performance-based teaching practices. Drawing from salient examples for some teachers, I center my discussion on these themes. I provide illustration for other teachers by giving vignettes associated with them.

In visiting and interviewing the participants, I noticed some participants were heavily involved in reform in regard to belief and practice. Others manifested change in belief with no apparent change in practice. Also, some showed reform in practice even though they disavowed belief in change. Hence, in some cases teachers possessed qualities that both confirmed and disconfirmed performance-based approaches.

In discussing teacher opinions about change, I use the following conventions:

1. Teacher reflections are attributed to research participants. A particular participant is identified by name with accompanying current teaching location, number of years in education, source of information, and date given in parentheses. After introductory information is provided, the participant's last name is used.
2. Pseudonyms are given for all places and participants.

3. In order to make the information user-friendly, some other identifying information is associated with each research participant.
4. A detailed list of participants is provided in Appendix E. In this list, a notation is given which indicates each individual's perceived proclivity toward change.

Factors that Encouraged Teacher Change

Factors that encouraged teachers to incorporate performance-based instruction in their math teaching included: dissatisfaction with student achievement and enthusiasm; ennui with current teaching; belief in educational research findings; influence of other teachers and departments; and revised teaching materials. Each of these factors is explored in the next discussions.

Factor one: Dissatisfaction with status quo.

Because they were dissatisfied with the current performance and achievement of their math students, many teachers embraced reform. Rita Rivera, a Presidential Awardee and former director of NCTM, taught for over twenty years and was greatly influenced by the original draft of the *Standards* and the teacher discussions it generated. Since those days she tried “to grow and improve as a professional.” Her interest in reform came from her teaching experiences. In her early teaching, Rivera taught book examples and then assigned the odds and thought she was teaching. Rivera realized “just because she’d taught it, didn’t mean they’d got it.” Weak assessment results, student comments, and bewildered student looks led her to investigate other approaches. Her current teaching is constantly evolving. Now Rivera finds or writes activities that investigate and analyze the concepts that she is teaching. For example, in examining properties of reflection, Rivera designed an activity that used a mirror on the floor and its associated reflections of objects. Rivera tried to “get kids to construct their own thinking—come

up with the concepts—and understand the concepts.” She knew it was important for students to understand why they were doing things, not just how to do them. Rivers said, “When you see the kids’ eyes light up, then you see the difference. That’s all you need to know: Okay! this is what we should be doing” (Rivera, high school and college teacher in neighboring state, 20+ years, personal interview and survey, 7/29/03).

Similarly, Sue Meyers often heard disparaging comments about math teaching from her sons in middle school and high school. Sue used suggestions from her sons in revising her teaching. Because she cared that students understood their math, Sue adjusted her teaching strategies to optimize class time and discussion. During the 2003-2004 school year, Meyers moved desks into groups in order for students to work together. Then, she gave students the challenge to create and solve their own equations; at lunch Meyers shared with other teachers the enjoyment her students and she shared with this assignment. She changed her teaching when she saw something worked; Meyers decided an assignment worked when her students displayed more understanding in their oral or written responses. Although Meyers expressed indifference about reform ideas, she incorporated some constructivist ideas in her teaching (Meyers, CHHS, 13 years, personal interview, 3/10/04).

After teaching in Europe with no formal teaching background, Amy Hansen attended college with a “curiosity about how teaching really works.” She was inspired by seeing the influence a teacher could have in a classroom. Hansen taught at West View and credited being “dissatisfied with what was happening in the classroom” as the motivator for changes to performance-based teaching. She believed students learned mathematics “by playing with it—by engaging, practice, explorations” and “the more students could experience, the more they internalized—the better they understood.” Hansen used projects and activities to provide the

experiential opportunities her students needed. One of her favorites was an activity that challenged students to consider probability in a new way. Each student was given a star-shaped object. The student drew from a box a percentage from slips of paper that had suggested percentages on them. The student challenge was to construct a game board on which the star represented the given percentage of area. Hansen believed this project pushed her students to think (Hansen, West View HS, 6 years, personal interview and survey, 8/25/03 & 2/13/04).

Dan Bennett, the youngest math teacher at CHHS, said, “If we continued to do the same things, we could expect the same results.” Although Bennett was reluctant to make changes in his teaching, he was aware his teaching failed to meet the needs of all students. He recognized some students required more hands-on instruction. In an attempt to involve his students, Bennett asked student groups to design games as review of a chapter. Although the student results disappointed him, Bennett commented that the students seemed to be enjoying the experience; he noted that refining the assignment and expectations would probably prompt better game boards (Bennett, CHHS, 5 years, personal interview, 2/23/04).

Factor two: Ennui with teaching.

Another prompt for math reform came from teacher views of their daily work—some teachers expressed ennui with the repetitive nature of their work before they revised their teaching. Vicki Hemple, a West View High School teacher, often became bored with other jobs. She saw math teaching as the “most frustrating, rewarding, tiring job that she had ever had.” Before changing her teaching to a performance-based mode, Hemple feared her teaching career would be short. She was getting burned out due to student apathy, lack of relevancy in curriculum, lack of interest in the curriculum, classroom management, and other educational issues. After Hemple incorporated the Understanding by Design elements into her performance-

based teaching and assessment, she had a renewed interest and enthusiasm for teaching. Because her students seemed more interested and involved in their own learning, Hemple enjoyed her teaching (Hemple, West View HS, 4 years, personal interview, 8/5/03).

In a similar vein, Seth Connelly, an experienced teacher from a neighboring state, saw positive changes in both his attitude and the attitude of his students after his incorporation of activities and projects into his classes. Seth liked having more variety in his teaching and assessment; he found teaching more fun and rewarding than previously. Since using more activities and projects, he no longer needed to explain to students “when will we ever use this?” (Connelly, high school and college teaching in neighboring state, 25 years, personal interview and survey, 7/29/03)

Sue Meyers said “boredom” often dictated educational change in her classroom. She felt that both the students and she got tired of certain things and needed to look for other options. When Meyers involved her students in writing equations that were challenging to solve, she gained more insight into some student work. In working with students who took two years to complete the Integrated 1 course, Meyers noticed this assignment prompted enthusiasm and involvement her students had not previously shown. The students were motivated to design equations that *stumped* other students; Meyers was impressed with some clever strategies. Other student-designed equations signaled the need for remediation or a new approach for them (Meyers, CHHS, 13 years, personal interview, 3/10/04).

Drew Miller was prompted to change when he was bored. “If I am tired of something, the students are also.” After visiting with Sue Meyers, Miller tried the *equation-writing* assignment with his students. Also, Drew used a Valentine assessment that required students to show the work in approximating the perimeter and area of a heart-shaped figure. Extra points

were awarded if the students showed various methods to approximate the quantities. Because Miller required students to explain their work, he gained information about their understanding from this assessment. Miller “can’t imagine enjoying math without understanding math. I can’t imagine enjoying teaching without seeing students enjoying math. If people are considering being teachers and don’t know the math, that’s pretty sad. It makes me frustrated and irritates me when I see teachers who teach or want to teach if they don’t know and appreciate mathematics.” Miller changed his approaches to help students appreciate math (Miller, CHHS and college teaching, 9 years, personal interview, 3/4/04).

Factor three: Belief in current educational research

Pete Sommers, a university professor and educator with thirty years experience said, “Teachers change when they feel the change improves performance in their classrooms just as individuals change their diets when they are convinced the change improves their health.” Sommers added, “People are resistant to change without any evidence that performance changes” (Sommers, university professor, 30+ years, personal interview, 10/2/03). Hence, some teachers changed their teaching when they researched educational literature and believed the findings.

A young teacher planning to be an administrator, Cindy Thompson, studied education during the reform years. Thompson said she “will try anything for my students!” She believed in challenging her students. She liked to get kids out of their comfort zones. She thought it was important that she was willing to do the same thing; her extra work for performance-based techniques had purpose. Thompson changed her teaching and assessment because she saw change as essential to educational progress for both students and teachers. Thompson believed students learned by adjusting to change; hence, her epistemological beliefs drove her teaching.

Thompson read educational literature and believed the constructivist approach was essential in a teacher's attempt to reach all students. Her husband, Mark, was also a teacher; they often discussed constructivist approaches they had used. Thompson liked one of the activities Mark developed with his students. When studying an astronomy unit, Mark and his students provided an example of performance-based work. Cindy witnessed first-hand the positives of active learning. When his students had completed the unit of study, they presented an astronomy fair for the community. The community and students enjoyed the evening, complete with stargazing, poster sessions, and games. Mark's students presented clear explanations of phenomena for the audience. Because Thompson adhered to constructivist views, she sought active activities and projects in her teaching (Thompson, CHHS science teacher, 6 years, personal interview, 8/12/03).

Amy Hansen's teaching reflected the constructivist views she studied in her college classes; she credited that study with changing her ideas about teaching. Hansen believed being aware of current education theory was one of the requirements for being a successful teacher. Hansen disapproved of projects in which some worked and all received the same grade. She liked to have students sit around, discuss, and solve a hands-on problem together. Then Amy had each student write out the solution independently. The assignments received individual grades. Hansen liked to use rubrics; she thought these made students aware of the objectives and standards used in their assessment. When I visited her class, the students studied various types of angles in circles. Using a complicated figure, students determined angle measure from a geometric drawing that contained many connected circles that included numerous types of arcs and angles. While Hansen gave students time to complete the activity, she reflected questions back to them when they asked for her suggestions. The students worked together to complete the

assignment; those who needed more time took their work home to finish (Hansen, West View HS, 6 years, personal interview and survey, 8/25/03 & 2/13/04).

Factor four: Influence of others.

Another support for change was the example of individual math teachers—those who embraced reform and continually worked to fine-tune it. Jim Endrew hoped more teachers would gain a passion for math and teaching. With enhanced teacher commitment and enthusiasm, perhaps students would be more excited about their math experiences. Because Endrew received his training from professionals who used performance-based teaching and assessment, he observed instructional examples that served as models for his teaching. When teaching pre-calculus, Endrew sought projects with which students could demonstrate their understanding. One of his challenges in the 2003-2004 year was verifying the trig identities his students had developed. That assignment required him to do some sophisticated substitution and assessment. He shared the project with other teachers; some used the same challenge with their students (Endrew, CHHS and college teaching, 10 years, personal interview, 3/17/04).

With passion and energy for mathematics education and educators that appear boundless, Dave Winters believed “the more active I could let me students be in their own learning, the better I thought they learned.” Winters had served as president of the hundred thousand plus membership of NCTM. In promoting reform, Winters thought the best way to encourage change was to make good materials available. Dave worked with others to write activities that supported student conceptual development in mathematics. He believed it took a core of willing reformers to influence others to make changes in their teaching. Example was a powerful motivator. In teaching prospective teachers, Winters used performance-based assessment opportunities. His college students investigated the treatment of burns in a hospital. In

discussing the challenges of treating burn patients, students learned that skin was grafted from patients in order to help with severe burns. One of the questions prompted from this scenario was how much skin could be safely grafted and from which areas of the body; there were guidelines on how much could be donated. In addressing this problem, students attempted to find a mathematical model of the average human body and its skin-grafting potential. Another example Winters enjoyed was when his students investigated whether birds should eat more or less before they migrated. He noted, “It was a problem in context and to do it they had to learn something about migratory patterns, a specific bird—because sometimes there might not be a generic answer for something like this—because some birds do fly their migratory path without stopping. Some stop—and the answers might be different, but trying to model this problem mathematically required good problem solving” (Winters, university professor, 30+ years, personal interview and survey, 7/28/03 & 2/26/04).

Rita Rivera credited mentors with helping her make systemic changes in her teaching. She worked at making incremental changes each year. Some of the changes were prompted by teacher observations. She also watched instructional videos to view other teachers and their classrooms. Rivera participated in many NSF- and NCTM-sponsored workshops and conferences. She believed if students could “understand, compute, apply, reason, and engage,” they were able to demonstrate math competence. Rivera noted that sharing activities was essential to growth; she said, “Asking someone to create an activity and then try to use it is too much.” After Rivera had used activities provided to her, she became comfortable with designing and modifying her own materials. Friends who discussed constructivist perspectives with her and provided excellent role models motivated Rivera to incorporate active teaching strategies

and materials in her teaching (Rivera, high school and college teacher in neighboring state, 20+ years, personal interview and survey, 7/29/03).

The fact that other departments and schools involved students in more active learning made performance-based work in mathematics a more attractive option. For example, as a way to explore the performance-based model and culminating projects, the world language department at CHHS designed student projects so that when their students went on a class trip to a particular country, the students worked on their associated projects. Since students had the opportunity to work on projects and activities in other classes, they received the training that encouraged the implementation process in math.

Factor five: Revised teaching materials.

One of the inherent challenges in systemic math reform was finding appropriate teaching and assessment materials. In the beginning stages of reform, teachers usually used materials they purchased or obtained through internet searches. As they began sharing with fellow reformers, they found other useful sources. Often teachers were pleased with the enthusiasm students showed in the reform assignments and activities (Rivera, Connelly, Manuel, Feltis). Their successful experiences with the materials encouraged the teachers to continue revising their assignments, activities, and assessments. After math teachers had tried these teaching materials, many developed their own teaching and assessment materials. When they had tested explorations, activities, and projects through classroom use, the teachers revised their writing. They worked with colleagues and shared success stories (Monesco, Ward, Munro, Hansen, Meyers, Miller). Hence, there was a common progression in the acquisition of reform materials. Teachers credited this process with influencing them to continue implementing reform (Rivera, Brown, Winters).

When the Crescent Heights math curriculum changed to an integrated mathematics approach, William Buck, the veteran math teacher at CHHS found the new material to be challenging. In order to teach from the new program, Buck learned new mathematics. He thought it was “very intimidating;” he credited the integrated math program with making him more aware of applications in math. Buck believed that learning integrated math ideas improved his teaching, but the process was difficult (Buck, CHHS and college teacher, 38 years, personal interview, 3/3/04).

After being an author and a teacher of one of the reform high school math curricula, Angie Feltis totally revised her views about mathematics. She claimed she learned more mathematics in helping to write different modules of the curriculum than in her college math years. Since using performance-based techniques to teach activities and problems, Feltis believed her students and she understood more mathematics than they previously learned using more traditional methods. Also, Feltis credited performance-based techniques with allowing more of her students to study more years of mathematics. In her years with the reform curriculum, Feltis saw her high school add about thirty extra students a year to a third math course. Feltis found numerous ways to explain ideas. She said, “If they didn’t understand it the way I explained it at first, if I explain it exactly the same way, then they’re not going to understand it again.” Feltis used a crazy cartoon module to teach transformations. Students determined coordinate points that formed a cartoon. Then they wrote a matrix for their picture that closed up the shape. Next, the students determined matrices that produced the required transformations. In assessing this assignment, Feltis checked to see whether or not her students understood transformations and could write matrices to do them. Feltis appreciated the fact she could use commercial materials to get started

on this module; she regularly revised activities, explorations, and projects to reflect her teaching preferences (Feltis, another state, 20 years, personal interview and survey, 7/19/03).

Marie Manuel sought projects and activities from various sources. She contributed to an on-line magazine that NCTM operated. Manuel enjoyed finding new ideas to share with colleagues. She credited new ideas, projects, and materials with inspiring her to change to more active teaching methods. In assessing student projects, Marie noted the variety of talents that her students possessed. One of her favorite projects for a calculus class was when her students designed a container that could efficiently transport a human heart necessary for a transplant. The students researched the requirements for the manufacture and promotion of their product. They produced a sample *heart-conveyor* with appropriate documentation involving the laws of heating and cooling to substantiate the fact their model was feasible. Then the students presented their models with accompanying explanations to a panel of doctors, students, administrators, and business executives. Manuel claimed their work was “incredible” (Manuel, neighboring state, 20+ years, personal survey and interview, 12/3/03).

Factors that Limited Change to Performance-Based Work

Although there were numerous factors that encouraged change to performance-based work, others deterred change. Factors that limited teacher change to performance-based instruction in math teaching were: beliefs about personality-teaching style links; satisfaction with job performance; disinterest/distrust of educational research; and the challenges of change. Even teachers who embraced reform found change challenging. In discussions about adding performance-based teaching practices, teachers consistently mentioned the associated challenges and frustrations.

Factor one: Personality/teaching style connections.

One of the reasons cited for math teachers' not wanting to change was a belief that performance-based teaching and assessment only worked for certain *types* of teachers. Some did not use performance-based work because they thought it just could not work for them. A barrier to teacher change was the role math teachers believed personality played in their teaching. Dan Bennett found any kind of change difficult. Because he had an inner drive to do things effectively, he did not like to take an idea and jump into using it. Dan wanted to have things planned out. He tried to think critically—to modify ideas so they would be more effective. He liked to take time for planning. Because time was a precious commodity in teaching, Bennett found it difficult to implement change. After students designed games that reviewed a chapter, Bennett was disappointed when the majority of students told him the assignment did not really help them any. He was not sure whether the students, the assignment, or a combination of other factors made the student project relatively unsuccessful. Bennett commented he was uncomfortable with that style of teaching and his discomfort probably showed (Bennett, CHHS, 5 years, personal interview, 2/23/04).

Because Sue Meyers knew she had a cynical side to her personality, she hoped students got to know her and appreciated her strengths. Because she discounted many educational claims, Meyers recognized her cynical “bend” kept her from trying some new ideas (Meyers, CHHS, 8 years, personal interview 3/9/04).

Our department chair Meadows claimed, “Generally, I am pretty quiet, an introverted person. I don't like to be up on the stage. I have to step out of my personality—be more of a showman to hold student attention.” He desired “enough creative imagination to come up with some good projects.” One of his favorite projects was a roller coaster design in which students

used parts of sinusoids to create a roller coaster that met certain criteria. In discussing the personalities of CHHS math teachers, Meadows appreciated both the “warm, fuzzy people and the mathematicians” who comprised the group. Meadows hoped the diversity of personalities offered good dialogue opportunities (Meadows, CHHS, 15 years, personal interview, 3/16/04).

Martin Compton, an experienced CHHS math teacher, attempted a few student projects and activities, but did not like the results. He had not decided why *active* student learning techniques disappointed him; he had not felt successful in implementing them. Although Compton admired those who could work projects effectively into their teaching, he did not envision adding performance-based work to his teaching in the next years. He acknowledged that projects probably “win the heart and mind [and so] the rest will follow.” He believed engaging students was an important element in successful teaching, but claimed, “Sometimes he had to force himself to be more energized” (Compton, CHHS, 16 years, personal interview 3/8/04).

Factor two: Satisfaction with job performance

Because he thought people believed he had done a good job in his teaching, the veteran teacher of the CHHS math group, William Buck, did not feel any pressure to change. He did not mind trying new approaches and appreciated teachers giving him activities and ideas. He had a teaching experience with performance-based teaching that backfired so he was a bit leery of that style. For completing a teacher-training workshop in which he monitored students who completed a business computer application, he received a computer. When commenting on that computer-based project, Buck believed he had not had time to assess the project well enough, revise it, and go from there. He had been pleased with the student writing, oral and written presentations, and computer work but had been disappointed in the student mathematical

understanding shown in the project. Hence, that project made him reluctant to use more performance-based work. Buck said, “He liked to set a task and get it done.” Buck expected the same thing from his students, “If I give them an assignment, I expect them to do it and to do it right.” Although he still had students who did not do their assignments, Buck said, “That’s the way I run my class” (Buck, CHHS and college teacher, 38 years, personal interview, 3/3/04).

Since Jim Endrew took college classes during the early reform years, he did not feel any pressure to change his teaching. Endrew believed he had learned good educational practices during his training and student teaching. He spent quality time reflecting on his teaching; he frequently asked students about their understanding. He did not have an elaborate way of obtaining feedback from students; Endrew simply asked individual students whether or not an activity or project had been worthwhile. Endrew believed his students were honest in their evaluations of his teaching; he used their comments to revise his lessons. Endrew planned to continue selecting projects and activities he felt enhanced his teaching. He did not sense an urgency to make changes (Endrew, CHHS and college teaching, 10 years, personal interview, 3/17/04).

The youngest teacher in the CHHS Math Department, Dan Bennett, was comfortable with his style of teaching and thought it was effective. Since he believed “no educational program ever goes to fruition,” Bennett was frustrated with the pendulum swing of reform. He thought there was pressure to change with “directives from above with no guidance from above.” Bennett said he would continue to explain math clearly to his students; he contended that those who did their assignments would do fine with his approach. He was aware some teachers incorporated performance-based assessment in their teaching; he did not believe adding those

components to his teaching would strengthen his classes (Bennett, CHHS, 5 years, personal interview, 2/23/04).

An experienced teacher who had completed his administrative credentials, Martin Compton was not confrontational, but “doesn’t want anyone telling him how to run his class.” Compton wrestled with the integrated math pace; he believed we pushed content at breakneck speed. Compton said, “We are not taking time to solidify foundational concepts.” He thought his style of teaching—making connections with students and explaining math well—appealed to many students. Compton did not feel pressured to add performance-based work to his teaching; he believed teachers try to do too much already (Compton, CHHS, 16 years, personal interview, 3/8/04).

Factor three: Distrust/disinterest in research.

Another barrier to math teacher change at CHHS was teacher lack of awareness of and/or distrust for educational and mathematics research. Dan Bennett looked at research as theoretical; he was learning the practical (Bennett, CHHS, 5 years, personal interview, 2/23/04). William Buck did not seek math or educational research because he considered himself “not an in-depth type of person” (Buck, CHHS and college teacher, 38 years, personal interview, 3/3/04). Drew Miller believed some research was bogus—offering packaged solutions from people who had been out of the classroom for years. He added, “Teachers wouldn’t want to ignore findings about calculator use and stuff” (Miller, CHHS and college teaching, 9 years, personal interview, 3/4/04). Patrick Clark thought educational research, in general, was stunted. He did not look for anything new because he thought research tried to defend the same body of knowledge that had been around for many years. He was taught by “the classical method. I took educational and behavioral psychology and I don’t think they change much” (Clark, CHHS, 16 years, personal

interview, 2/24/04). Teachers believed they adjusted their teaching to all the other variables present in a typical classroom. Some teachers thought the pendulum of reform would switch back to more direct teaching and then they would be *current*.

Factor four: Challenges of change.

Most math teachers were overwhelmed with the content vs. coverage ideas. They noted that students don't have enough practice in obtaining basic algebra skills and that projects and activities took away from needed practice time. Many of the math teachers said more was demanded of teachers now, but *not* in the area of mathematics. Patrick Clark said, "Because of the one-size-fits-all theory of this district, teachers have a much broader range of students to deal with." Patrick thought it was difficult when you had kids who had no conceptual foundation at all and gifted kids in the same class. He found the culminating project and other mandated educational directives "ludicrous because teachers didn't have the luxury of time to develop the critical thinking students needed to guide people along the way" (Clark, CHHS, 16 years, personal interview, 2/24/04).

Jill Jones taught both math and psychology; she found it easy to use activities and projects in psychology. Psychology students discussed and debated many ideas. In math, Jones struggled with the *coverage versus concept* dilemma; she found it difficult to fit projects and activities into her math teaching. Jones worried her students would not acquire the necessary skills to be successful in their next class (Jones, CHHS, 10 years, personal interview, 3/9/04). Some math teachers expressed the opinion they were willing to try projects and activities, if others provided them. Many mentioned time management as the reason they did not use more projects and activities. They commented that it took time to find effective projects and it took class time to include them in instruction. Jim Endrew, our board certified teacher, was selective

in his use of projects and activities. He evaluated whether the project or activity was worth the class and outside time required for completion. He gave very clear directions and expectations when he assigned projects to younger students (Andrew, CHHS, 8 years, personal interview, 3/17/04).

After being a college teacher and researcher in math education for more than thirty years, Pete Sommers recognized the many challenges in teaching and commended teachers for their altruistic views. He pointed out that teachers were “good people—who want to do the best for their kids. They don’t purposely try to send *dumb* kids out!” In studying change, Sommers noted people who made changes to their teaching went through various stages. He knew it was very hard to change (Sommers, university professor, 30+ years, personal interview, 10/2/03).

Dave Winters, a former NCTM president, thought “teachers have to start realizing that they aren’t going to have the answers to all the student problems when they are doing performance-based work because they have to be open to student ideas.” He believed, “It takes more knowledge to do performance-based teaching than just to follow a text book. And it takes an openness that some teachers don’t have.” Hence, Winters credited the amount of work involved with the reluctance of some math teachers to change (Winters, university professor, 30+ years, personal interview and survey, 7/28/03 & 2/26/04).

One of the major challenges to changing teaching was finding time to implement change. CHHS math department chair Jeff Meadows regretted the math teachers at Crescent Heights did not share an office so they could have a common area in which to work. He believed teachers should only teach four classes a day with an extra hour for collaboration. He also wished more teachers had the opportunity to observe others; he found his visits to other classes invigorating and helpful. Meadows was interested in lesson study as discussed in *The Teaching Gap* (Stigler

and Hiebert, 1999). He planned to encourage CHHS math teachers to spend time developing and discussing lessons (Meadows, CHHS, 15 years, personal interview, 3/16/04).

How Teacher Epistemologies and Ontologies Affected the Change Process

The final section of this chapter discusses teacher views about mathematics and about how people learn math. The chapter also describes the effects of teacher beliefs on their willingness to change to performance-based instruction. In other words, the section presents the ontologies and epistemologies in the context of mathematics for various teachers. Also, the section addresses the effects of teacher views on systemic change to performance-based work.

Teacher Views about Mathematics.

In general, teachers who viewed high school mathematics as an unchanging discipline did not adopt a performance-based approach. Our math chair, Jeff Meadows, contended that math did not change, but our approach did. He said, “We are getting away from teaching algorithms and process to teaching content and concept.” Meadows had taught in various states and noted the same general questions and frustrations continued to stymie teaching efforts. Because he was taking college classes that discussed leadership and motivation, Meadows worked to motivate others and him to address recurring educational issues. Meadows believed in being practical about reform efforts. He was cautious about implementing mandated programs. One indication Meadows was reluctant to embrace performance-based learning was his hesitancy to provide a list of suggested culminating projects in math to the IMPROVE group. Although other departments had listed projects, Meadows had not provided the required list (Meadows, CHHS, 15 years, personal interview, 3/16/04).

After being an engineer for a number of years, Henry Lloyd began his teaching career. In his seventh year at CHHS, Lloyd said, “I’m fifty-seven years old. I’m not feeling pressure to do

anything—just the right thing!” Lloyd did not believe mathematics changed over the years. He doubted our current students needed all the mathematics we were encouraging them to take. Lloyd thought many students had so many other serious problems that they should be given “worksheets” to do in class so they could take their math and “be done with it.” He said, “We only need so many mathematicians in this world anyway.” Lloyd believed some students did not have the ability to understand the concepts we were exploring. He thought these students needed more reinforcement and practice in order to pass their classes. Lloyd knew many of these students would do *fine* in life without a lot of math (Lloyd, CHHS, 7 years, personal survey and interview, 2/11/04).

Patrick Clark did not see much change in high school mathematics over the years. He saw math as a language of modeling our world. “We use mathematics to either understand, plan, or predict things that are happening.” Clark believed the “body of math changes, but not at the high school level. Most of the math we are teaching is one or two thousand years old” (Clark, CHHS, 16 years, personal interview, 2/24/04).

In contrast to the views of some other math educators, Dave Winters, former NCTM president, believed math was constantly changing and teachers needed to make the requisite changes in their teaching. Winters said, “Teachers should never stop learning; mathematics content is not static.” As previously mentioned, Winters actively involved students in explorations, activities, and projects in order to have them construct their mathematical understanding (Winters, university professor, 30+ years, personal interview and survey, 7/28/03 & 2/26/04).

Teacher views about how people learn mathematics.

The participants expressed differences in the ways they viewed student learning. These views often influenced their teaching practices; the ideas helped determine whether or not teachers used performance-based instruction. Often teachers who did not incorporate performance-based activities and projects in their teaching believed students learned by traditional methods—in which practice was stressed. Martin Compton, an experienced CHHS teacher, believed students learned “absolutely and totally and unequivocally inductively—trial and error—figuring out what was right and repeating it—and what was wrong and eliminating it.” Compton thought his teaching strengths were that he connected with students and made them comfortable in math class. Compton did not believe performance-based approaches would improve his teaching (Compton, CHHS, 16 years, personal interview, 3/8/04).

Some teachers were satisfied their knowledge about math teaching and learning was sufficient for them to teach well. Patrick Clark had two basic—rather broad—ideas about the way people learned math. He believed math was painful for some students because they learned it as a detached set of definitions and rules they simply memorized—and that was why math was so painful for them. The other students learned by thinking in terms of the language. They realized there was “connectiveness” in topics and they could come up with their own methods of solution. These methods were mathematically, conceptually, and notationally correct. “Very few students get to this point.” Clark did not believe different methods would bridge the gap for most students; he thought lack of student interest, effort, and/or ability explained student failure (Clark, CHHS, 16 years, personal interview, 2/24/04).

Drew Miller, CHHS and college teacher, asserted CHHS had a math department with capable and creative teachers. Drew said, “It would be horrible to not teach our students the

mechanics to get to the broader stuff.” He then added, “We’d be slave drivers if we never taught them to enjoy it along the way.” He agreed with a student comment that learning math can be “a lot of irritation.” The student pointed out that oysters needed irritation to make pearls; perhaps people needed some irritation to learn math. Miller used projects and activities when he believed they were worth the time and effort; he thought students needed more practice with algebraic manipulations than they received (Miller, CHHS, 12 years, personal interview, 3/4/04).

Dave Winters had different beliefs about how people learn mathematics. He pointed out that his belief in active teaching was an observational thing, not research. He incorporated student activities in his teaching because he believed his observations. Also, he knew the perception of who could and who could not learn mathematics needed to change in order for systemic change to occur. He “believed strongly that everyone could learn mathematics and that they could learn it in an intellectually honest way. If we thought that only a few could learn it, we were making a terrible mistake.” As mentioned earlier, Winters adhered to constructivist views and incorporated performance-based approaches in his teaching (Winters, university professor, 30+ years, personal interview and survey, 7/28/03 & 2/26/04).

Jill Jones thought people learned in a variety of ways. She remarked, “When I went to school, you had to do things in a certain way.” Jones mentioned she recently asked a student to find the midpoint of a segment. She was surprised that instead of using a formula, the student graphed the segment and physically located the midpoint. Jones appreciated that today’s teaching methods encouraged and anticipated different approaches (Jones, CHHS, 10 years, personal interview, 3/9/04).

Generally, teachers who had not made systemic changes in their teaching were satisfied with their job performance. When necessary, they made requisite changes to their work. Using

a variety of measures, they assessed the success of their teaching and changes. Also, reformers took years to make changes in their teaching and had various ways of determining whether or not their changes were helpful to their students. The ideas of both groups are presented in the next chapter.

Chapter Nine discusses the second research question:

How do teachers determine whether systemic changes to teaching have been made in their own practice and whether these changes have affected student performance?

Chapter Nine

Teacher Perceptions of Their Changes

In discussing how they determined whether or not systemic changes had been made in their teaching, teachers were quick to categorize themselves as what I refer to as *reformers* or *resisters*. Although such characterization is not entirely accurate because change was measured on a continuum, the grouping does provide an efficient way of organizing teacher responses. In addressing whether teaching changes have affected student performance, the reformer and resister groups provided responses in line with their ontological and epistemological views. Teacher responses to the research question about change and its effects are divided into separate sections: one for the *reformers* and one for the *resisters*. In categorizing teachers, if few change indicators were demonstrated, the teachers were *resisters*. Because those who remained uncommitted to change to performance-based work had more characteristics in common with the *resister* group, they were labeled *resisters*. As previously noted, if no classroom observations were made, the teacher's self-perception was used; occasionally this perception did not agree with my records. For quick reference, participants with their labels are listed in Appendix E.

Although CHHS teachers were involved in a systemic change process, it is interesting that both *reformers* and *resisters* had representatives in the math department. In the following section, the responses provided by those who favored reform are discussed. As a reminder, some of these teachers were members of the CHHS Math Department.

Reformers: Extent and Effects of Their Changes

Reformers credited changes to performance-based teaching and assessment to their personal commitment to the change process, their beliefs about math, and the teaching of math

(Winters, Rivera, Manuel). They viewed change as an on-going commitment. The reformers commented about changes they had made; the changes often involved incorporation of more active student learning practices.

I started teaching the same way I was taught. It was a struggle and I was starting to feel burnt out. The last few years I changed my teaching. I worked with others to revise projects and activities that we designed. If it weren't for that, I would not want to be teaching. It was wearing me out real fast (Hemple, West View HS, 4 years, personal interview, 8/5/03).

I have totally changed the way that I teach. I've put a lot more time on applications, explorations...helping kids understand why math works...why a certain concept works and why we'd want to use it...I expect students to understand why certain things work (Feltis, another state, 20 years, personal interview and survey, 7/19/03).

As noted earlier, Rivera and Connelly changed from the review, show, practice model to more active learning techniques. Connelly said, "At first I was saying 'Oh, this will never work,' but then I piloted some reform materials and found out Hey! I really liked what was going on." He used technology to introduce and reinforce what students learned (Connelly, high school and college teaching in neighboring state, 25 years, personal interview and survey, 7/29/03).

Some teachers mentioned that resistance from students or colleagues made them aware that they had changed their teaching.

I had a power struggle at the beginning because kids would say, 'Just show me how to do it'...and I had to discuss the fact that that method didn't work to help them remember things. When a new kid came in my class and started complaining because I wasn't showing procedures, another student said, 'You just be quiet because you will learn more

math in this class than ever before.’ The latter student was one who had resisted the most...Lots of kids have never had to think...they just repeated back (Manuel, neighboring state, 20+ years, personal survey and interview, 12/3/03).

I think some people are really threatened by trying something new and maybe going in front of a class and not knowing what they are doing or not having success or not having the answer. They are not willing to take that risk; it is so much safer to go in and talk to the white board” (Rivera, high school and college teacher in neighboring state, 20+ years, personal interview and survey, 7/29/03).

Most reformers believed *resisters* motivated them to become more effective teachers and helped them monitor their progress. Some reformers admitted they became frustrated with the lethargy of some co-workers. When discussing math and its teaching, reformers exuded confidence and exuberance. These teachers thought math education reform progressed slowly. However, regardless of the pace of reform, most believed math reform efforts enhanced math teaching and learning. Although many of the reformers had been involved in change for the last ten to fifteen years, these teachers believed more active teaching, learning, and assessment still provided the keys to improved math education (Manuel, Connelly, Winters).

Reformers provided information about the effects of their changes to performance-based work. Most admitted it was very difficult to both teach and research. They mentioned that student comments, achievement, expressions, and suggestions provided feedback on their reform efforts.

I’m not convinced that our assessments really measure what we think they do. I think that is the toughest. In the last couple years, I think the biggest indication is in the relationships that I have with kids. If they enjoy being in my class and trust me, then they perform

better. I mostly just look at if they are attending...working...have a good attitude...that helps me more than looking at their overall grade. If it's performance-based, I look at my assessments, so I can tell things from them (Hemple, West View HS, 4 years, personal interview, 8/5/03).

Teachers involved in reform observed that their students were willing to tackle open-ended problems; the students did not seem stymied by non-routine challenges. Thompson used different types of assignments and assessments. She said, "I look to see which students are connecting strongly with the activity or the assessment and which ones aren't." Thompson tried to balance assessments so she reached students in different ways (Thompson, CHHS science teacher, 6 years, personal interview, 8/12/03). Jones had "students show they know things in a lot of ways. I monitor while they work—have them work together—go around and ask them questions" (Jones, CHHS, 10 years, personal interview, 3/9/04).

As described in previous chapters, Feltis, Manuel, Connelly, and Rivera credited performance-based work with encouraging their students to think and to enjoy challenges. Their students suggested their own strategies instead of waiting for them to provide ideas. They also talked about differences in achievement and attitudes of their students. After using projects and activities, Munro and Connelly noticed positive changes in their students. Because learners were unique, reformers insisted on variety in math presentation and assessment for their students. Reformers commented on how much more they enjoyed their teaching; they reflected on the mathematics their students and they were learning (Feltis, Rivera). Teachers knew personal analysis of their change might not convince others of the benefits of change; those involved with SIMMS added credence to their success accounts by providing documentation (U. S. Department of Education, 1995).

In working and research with NCTM, Winters mentioned some indicators of effectiveness: standardized test scores, performance assessments, and number of students taking more mathematics. He commented, "I think the goal should always be every student should have access to intellectually-honest mathematics for every year the student is in high school" (Winters, university professor, 30+ years, personal interview and survey, 7/28/03 & 2/26/04).

Resisters: Their Ideas about Change.

In contrast to this group, the *resisters* did not think they needed to make systemic changes to their teaching. Individual teachers resisted change for a variety of reasons. Some believed there was insufficient evidence to support change to performance-based work in mathematics. Certain CHHS math teachers said they did not have time to use experimental methods and materials in their teaching. Many did not belong to professional organizations; they were unwilling to invest time or money in NCTM. They pointed to their own successes as students as reason to continue in their current instructional mode (Meadows, Brown, Lloyd). Many interviewed teachers expressed the opinion that although teachers constantly revised their work, systemic change in their teaching was not needed.

Some resisters had personal reasons for not making systemic changes in their teaching. One math teacher said he did not want to learn more mathematics. He planned to complete the minimum requirements necessary to maintain his teaching certificate. Because some of the math teachers were highly involved in family or personal interests, they were not interested in devoting more time to educational work. One teacher commented he did not get paid enough to invest more time in his work.

Some *resisters* believed factors other than teaching modes limited student math progress at CHHS. First, student preparation for high school mathematics was lacking in many CHHS

students. Teachers blamed inadequate mathematics training in elementary and middle school math teachers as the cause of this weakness (Math Department meetings, January-March, 2004). Second, many CHHS math teachers believed student apathy and personal problems prevented the existing math program from being as effective as it could be (Bennett, Buck, Meadows, Clark). These teachers reported that students who did their part in learning succeeded in mathematics at Crescent Heights.

I explain things from more than one perspective. I use analogies and mnemonics to help kids remember . . . I have a class structure—detailed way so kids will know at any time what the expectations are. When they don't meet those expectations, they have consequences. If they are not meeting expectations, I give them a chance to recover; but then if they don't follow through, there are consequences (Bennett, CHHS, 5 years, personal interview, 2/23/04).

Because many CHHS math teachers considered themselves highly motivated and successful teachers, they did not seek systemic reform. Some mentioned that their math knowledge boosted their teaching effectiveness (Compton, Andrew, Miller); some credited the fact that students felt comfortable in their classes for teaching success.

I think I am pretty friendly and approachable and so I try to incorporate that in my teaching. I feel like I connect with people fairly easily and so that is going to influence whether or not they will ask questions. I try to get to know them so I know how to talk with them—cause every student is different (Clark, CHHS, 20 years, personal interview, 2/24/04, observations, 1/12/04 & 1/26/04).

When *resisters* made changes in their teaching, they had various ways of assessing how the changes affected their students—most involving student comments, achievement, expressions, and suggestions. Clark explained:

Without doing a statistical study, there was really no way to tell whether changes were beneficial to students—other than what we felt was happening. That’s the tough thing about teaching. We can’t really do research on our own students—even if we could we probably don’t have the time. We don’t have statistical evidence to back up what we are doing; we just have to have a lot of faith as teachers (Clark, CHHS, 20 years, personal interview, 2/24/04, observations, 1/12/04 & 1/26/04).

Although the majority of CHHS math teachers appeared reluctant to make systemic changes in their teaching, there were some indications that the math department, and in particular certain teachers, revised educational approaches. Chapter Ten discusses changes that took place in the math department at CHHS. It provides both student and teacher views of reform there.

Chapter Ten

CHHS Math Department and Change

In order to discuss change to performance-based work in math teaching and assessment at CHHS, we consider a variety of changes that occurred during the 2003-2004 school year. This study was complicated by the existence of numerous entities—CHHS as a school, various departments at CHHS, CHHS Math Department, CHHS math teachers, and other individuals at CHHS—all involved in change processes. The complexity involved in working with this dynamic web of change groups exacerbated the assessment of change. Various change scenarios will be presented in this chapter, while their associated implications will be discussed in the following chapter. Because general changes to CHHS impacted the math department, we shall first discuss general reform at CHHS.

Comments About Change at CHHS

Students, teachers, and administrators were involved in the reform process from 2000 through 2004. Some of the reform was driven by the IMPROVE grant. The state-mandated exams and culminating project also prompted reform. In order to facilitate reform, various teachers and departments offered special teacher classes both in preparing students for the state exams and in using performance-based techniques. During the second semester of the 2003-2004 school year, approximately twenty teachers completed a mini-course on reading in the content area. Five math teachers finished this training.

Teachers from various departments were encouraged to visit other teachers and their classes; however, only a few teachers actually made visits. In faculty meetings, CHHS administrators suggested teachers look at their own building to find examples of excellence. Leaders reminded teachers that they were overlooking a rich change motivator.

Teachers prepared students for the state-mandated tests. Because information about the exams and culminating projects was on the news, students asked questions in class about the effects of both the projects and the exams. All teachers were asked to monitor the progress of their students; they were expected to provide students with assessment experiences that mirrored the state-mandated exams. Since student input was needed and wanted in CHHS reform efforts, student comments made during interviews over the 2003-2004 school year provided information about change. The next section gives a summary of student responses about mathematics study.

Student Comments about Change in Math

One way to assess change to performance-based work in the CHHS math department was by listening to what students said about their math education from 2000 to 2004. The department changed from a traditional algebra, geometry, advanced algebra and trigonometry, etc. sequence to an integrated mathematics sequence in 2000; the graduating seniors of 2004 were the first group to have completed the series. The traditional vs. integrated math question complicated the assessment of change. Some students thought they would have received a better understanding of math if they had studied under the former system. They believed the integrated math program did not give them enough practice and time with one idea—the books skipped from topic to topic. Others mentioned the integrated books were easy to read and study on their own; they liked the applications in the books. Also, these students said they were not bored under the integrated system. They liked the variety of topics provided by the program. These student ideas may or may not have reflected teacher views.

Students interviewed during the 2003-2004 school year represented a select group since they were in their third year of math study. Because I received similar responses from the students I interviewed, I provided a summary of the received comments. Students who had not

completed three years of mathematics had not received enough experience with various math teachers and concepts; hence no attempt was made to interview them. Realizing the views of successful students were the only ones presented, I was somewhat surprised with the lack of change in math teaching the students described.

When asked if they had seen any changes in the way their math was taught over the years, most students said they had not seen changes. Participants said teachers had different ways of organizing their classes, but most instruction was basically the same. Marty noticed changes in her other classes; she did not believe there were changes in math class. In most classes, students participated in discussions and presentations; in math, tests and quizzes were used for assessment. Marty wished math tests did not count so much. She made small errors on her exams and preferred being asked to explain orally at the board in class. She believed she would have to know what she was talking about in order to give a complete explanation. Alek said he did not notice any changes; in math the teachers “always showed you how to do a problem and then assigned a bunch of problems.”

Ashley believed there was more participation in other classes than in her math class. She thought math was more repetitive than other classes. One great point about math class was Ashley “could ask any questions you wanted at any time and you could get an answer.” Because Alek liked to work by himself and study on his own, he wished math teachers would let students try problems before explaining everything to them. He said, “I’d rather have my assignment before and try it first and then get help—because I usually know how to do stuff.”

If Marty could have changed anything about math class, she would have changed the amount of time the teacher talked. Marty added, “I didn’t like it when a teacher was up at the board and talked the entire class time. It was really hard to concentrate that long.” She enjoyed

teachers who used engaging discussions, activities, and projects. Meredith agreed. She said, “Teachers who talk the majority of the period are talking way too much!”

Marty thought there were too many notes to record in math. Ashley did not like “taking notes all day.” She lost focus when she was trying to write down everything. Ashley said one of her math teachers was so excited about math that it was difficult for students *not* to be interested. She enjoyed this teacher’s enthusiasm. Most of the interviewed students liked working on explorations, activities, and projects. Generally, Meredith liked to work alone in math. She enjoyed honors classes because teachers identified “what was expected and [the students] produced.” She did not believe that working with others in math would be helpful because “basically [math is] cut and dry; that’s what makes math what it is.” Alek said:

This year I have tried to understand why I do things...I think lots of students just think about how to do things. I don’t think hands-on stuff is only for grade school. I think it helps high school students.

Most students noted they had seen members of the math department working together. The students believed their math teachers were still learning; they liked to hear their teachers discussing math and teaching (Student interviews, January & February, 2004).

Reform Work by the Math Department in 2003-2004

Another way to view change in mathematics teaching and assessment was to consider the work accomplished by the department. Besides participating in Understanding by Design training (Wiggins & McTighe, 1998), math teachers at CHHS were involved in focus groups for the IMPROVE grant. The focus groups met every few weeks during Thursday morning access times. Some teachers were in the reading group; these teachers ridiculed the particular book they read. Many admitted they read only the first few pages before deciding they were wasting

their time. They said the book that discussed the “genius” in all students was too idealistic and far-fetched. A few math teachers remained in the reading group to read other selections; others attended new groups. Several math teachers were specially trained to work as advocates for under-achieving students. These individuals believed their work was important yet were disappointed because they missed some math department meetings. Some math teachers worked on the special groups that focused on ninth or tenth grade students; others participated in a group that worked to improve the state-mandated test scores for CHHS. A few teachers joined the performance-based group that became the culminating project/focused area of study group. Some others chose a different focus group each time or worked in their rooms and avoided focus groups altogether.

During department meeting times, math teachers worked in groups based on the courses they were teaching. As a math department, they had bi-monthly discussions about how they could help students understand the big ideas that were important in the chapters. The teachers who taught the same math course spent time coordinating schedules and testing times. As a department, they formatted the integrated math exams so the tests followed the same structure as the state-mandated tests. Teachers who taught the same integrated math course organized the exams for the remainder of the year so a few teachers were responsible for designing each exam under the mandated test format. In revising exams, the teachers wrote some multiple-choice questions, some short answer questions, and some extended response questions. The problems were in the same ratios as the same types of questions on the state exams. Math teachers set up a schedule so all teachers were involved in reviewing and writing the exams.

Because improvement in performance on the state exams became an important objective for the school, individual math teachers took classes about reading in the content areas. These

teachers participated in an inservice; they took a typical state reading exam and then graded the exam in order to familiarize them about the testing. Other math teachers continued in advanced training in Understanding by Design.

Changes Made by Math Teachers

While departmental changes were important, reform efforts by individual teachers provided other evidence of change. During the 2003-2004 school year, four math teachers at Crescent Heights arranged their classrooms in new ways. Some tried grouping desks in the room instead of leaving the desks in rows. Others tried projects for the first time. A few teachers asked other teachers for materials that worked for particular math topics. They shared ideas that had been successful in their classes. The department chair Meadows e-mailed math teachers various articles, test scores, and other educational materials. Administrators and the school librarian notified math teachers of recent educational research. Because the principal retired at the end of the school year, the CHHS faculty selected three teachers to help in the selection of a new principal for the school; all teachers were invited to submit information on the qualities the new principal should have. Teachers shared conversations about the direction of CHHS.

In general, math teachers decided that the textbooks directed their teaching. At department meetings, they were told the district, with teacher input, would determine expectations for each course. Previously, collaborative planning consisted of scheduling of exams and pace for particular chapters of the texts. Now student learning goals and objectives would guide planning. As teacher Drew Miller noted, "If you don't have any target, you hit it every time." He was pleased that math classes would be based on standardized course objectives. Several math teachers offered to be on book selection and course expectation

committees for the district. Most teachers expressed opinions during math meetings—although there continued to be certain teachers who did not give input.

A hierarchy of teachers existed in the department; there was still a separation of teachers into meetings by course title. The department spent time in our bi-monthly meetings discussing teaching methods and philosophies. Many teachers were frustrated that the same topics they stressed in Integrated 1 were re-taught in Integrated 2 and Integrated 3. The question that remained unanswered was, “Why don’t the students know and remember the ideas like slope and proportional reasoning?” Although a few teachers gave constructivist views about why students did not remember and understand the concepts, others said that student habits and characteristics explained the failure.

Changes Related to Using Performance-Based Methods

Changes made by the math department indicated slight progress toward incorporation of performance-based work. One strength of the integrated texts was that they provided activities and projects that made performance-based work easier to incorporate in our teaching. A few math teachers at CHHS knew about and/or believed in constructivist ideas; they suggested the math department incorporate more performance-based work in math classes. Marie Brown and Jim Endrew read literature that was suggested; Sue Meyers took the information and sought time to read it. Lectures and note-giving were still the most commonly employed instructional modes with Crescent Heights math teachers. According to the district math supervisor, Nancy Beckwith, some teachers discounted new methods without really giving them a chance. In her discussions with teachers, she found that some teachers contended that giving a demonstration to a group was the same as allowing students to investigate ideas themselves. These teachers thought they had used reform materials, when actually they had mis-used the materials. Hence,

certain teachers never actually tried new methods. With the integrated text, most teachers mentioned that they did not have time to use the ready-made activities and suggested projects.

On the other hand, some math teachers expressed admiration for teachers who had successfully employed performance-based assessments and teaching. Martin Compton expressed surprise at the quality of the fountain projects produced in some Integrated 2 classes and said:

I think about projects and am baffled about the quality. . . projects I have tried have been mediocre. Sometimes I look at cooperative learning and think there's not enough thinking going on (Compton, CHHS, 16 years, personal interview 3/8/04).

In a similar vein, the math teachers read student math posters that lined the hall outside one classroom. The posters gave student representations of math topics such as Cantor's infinity ideas, chaos, and fractals. Some students and teachers complimented the work.

Secondly, some CHHS math teachers tried new activities and projects. Marie Brown used an activity provided by another teacher that asked students to find the surface area and volume of four things: a cylinder that held candy, an individual candy that was a frustum, a rectangular prism that held another kind of candy, and the associated candy that was lozenge-shaped. Brown observed that students became engrossed in the project; she also noted that the correction time increased because of the variety of answers and approaches. The pre-calculus teachers used the parabolic hot-dog-cooking activity. They revised the activity to provide better assessment information. During the unit on surface area and volume in Integrated 1 classes, teachers asked students to calculate the surface area and volume of actual objects as part of their assessment. When discussing arc length and sector area, Henry Lloyd brought in a large wheel that his students measured. On the last day of school, several teachers visited a room in which

various objects were used with bubble-making solution. These teachers appreciated the enthusiasm the activity created.

Changes in Math at CHHS

In discussing change in the department, the realities of the change process should be considered. Because teacher change requires time and support, it will take time to really assess change in the math department at Crescent Heights. During teacher interviews and observations, some teachers discussed change but there was little evidence of systemic change in the department over the year. In the next chapter, a summary of my findings is presented along with conclusions, implications, and suggestions for related research.

Chapter Eleven

Summary and Conclusions

Summary

This research investigated math teachers at Crescent Heights High School and the changes these teachers made during the 2003-2004 school year. Changes in the math department were documented as well as changes in individual teacher practices. Since the first wave of math reform occurred over fifteen years before this study, the members of the math faculty who were not familiar with constructivist theories of learning had been unaware of educational theories for a number of years. Prompts for this study came from the challenges to reform presented by teachers who resisted and/or were unaware of the movement for a number of years. Since change to performance-based learning and assessment was a mandated part of the school IMPROVE grant, the math teachers had impetus to change their math teaching. The next discussions provide a summary of information about the two research questions. Names in parentheses after each discussion delineate participants who espoused some of the described views.

The study considered two major questions. The first question can be discussed using three related parts. The first part of question one addressed which teacher attributes, professional knowledge, and skills supported change to a performance-based model of instruction and assessment in mathematics. The following discussion gives the characteristics demonstrated by those who made changes to performance-based instructional approaches.

In analyzing teacher interviews, surveys, and observations, several teacher attributes emerged. Teachers who made changes to performance-based models were risk-takers. They did

not expect everything they tried would succeed. They were willing to experiment in education—to try to improve the status quo. When learning approaches or materials were unsuccessful, these teachers made revisions until they were satisfied with the results. These experimenters had confidence in their own math and teaching abilities, but also provided evidence they had faith in the abilities of their students. They displayed enthusiasm for teaching and mathematics. Some teachers who supported change to performance-based work believed mathematics changed through the years. Most of them had fluid skills in the use of technology and other tools that facilitated math teaching. They enjoyed collaborating with others; they were willing to share their educational finds. Those interested in change to performance-based teaching and assessment believed mathematical and educational research were beneficial. Most were aware of current research about both mathematics and education. These teachers admitted they could not know everything about mathematics and teaching; they judiciously reviewed research literature (Rivera, Sommers, Munro, Monesco).

The second related part of the first question asked which teacher attributes, professional knowledge, and skills deterred change. Those teachers who resisted change to performance-based work questioned the advantages of that mode. They were satisfied with their teaching; they believed they were successful under didactic methods of instruction. They thought students appreciated structured, thorough explanations in order to comprehend major ideas in mathematics. Most used notes, careful lectures, and discussions to develop math understanding. Many math teachers who resisted performance-based work believed their training in mathematics and teaching experience qualified them to control the pace and development of class work. Some of these teachers attributed poor student performance to lack of student effort and/or ability. Many stated that home factors often made student success unlikely. Most of the

teachers who resisted reform believed mathematics did not change over the years. They said that students who did their part in the educational process succeeded in CHHS math courses (Lloyd, Clark, Meyers, Meadows, Miller).

Many distinctions between characteristics of math teachers who were interested in reform and those who were satisfied with current teaching related to teacher views about math and math teaching. A final part of the first research question considered how teacher beliefs about math and math teaching affected the change process. Teachers who were interested in making changes to performance-based teaching believed they could find activities, projects, and assessments to engage students who had diverse learning styles. In fact, these teachers thought they had a responsibility to adapt their teaching to meet varying learning styles. Teachers who embraced reform worked to improve student communication in their classes. These same teachers believed practice was important; however, the teachers selected assignments and reviews that offered constructivist opportunities for learning. All in all, there was a look in the classes of those who supported performance-based work that reflected teacher confidence in the constructivist theory of learning. These teachers supported group work by students; they provided opportunities for students to complete a variety of assignments, projects, and problems (Manuel, Connelly, Andrew, Feltis). Also, teachers who made changes to their teaching viewed teaching and learning mathematics as challenging endeavors; these teachers felt a responsibility to stay informed about recent education and mathematics reform. Many reform leaders considered teaching a profession, rather than a way of making a living. In their interviews, the reformers mentioned education or math publications; they discussed their membership in professional organizations. Those who supported reform claimed their professional organizations and journal articles were catalysts for their incorporation of performance-based

work. Seeing a need for change, they considered awareness of research and reform essential components of their jobs. These educators held strong views about the importance of teaching and learning mathematics (Feltis, Sommers, Manuel, Hansen). The reformers had taken years to make changes in their teaching and had various ways of assessing whether or not their changes were helpful to their students. Their methods of assessing their teaching changes will be discussed in a later part of this chapter.

On the other hand, teachers who believed math did not change tended to be custodians of knowledge in their classrooms. Hence, these teachers were reluctant to make changes in their teaching. Often these same teachers stated they did not feel pressured to change because they felt they were already doing an exceptional job. Many teachers believed educational theories vacillated from one position to another; the teachers thought they held an anchoring position in providing some stability in the educational process. Some who resisted reform contended that after all was said and done the teaching community would return to the position of equilibrium these teachers supported. Teachers who resisted change stated their teaching style was bound to match the learning style of many students; hence, another teacher's style would be available for other students. Another belief by some who resisted change was that students needed to learn how to adapt to different teacher styles—that it was the responsibility of students to figure out how to succeed in any class. Teachers who resisted reform to performance-based modes supported more practice as the essential element of student math learning (Olson, Lloyd, Jones, Compton, Bennett).

McLaughlin and Talbert (2001) described two distinct cultures in school communities. In one community, teachers sorted students into courses “ranked by depth and difficulty of academic content” while in the other, teachers “collaborated to engage all students in deeper,

conceptual understandings of subject matter.” Although the district to which CHHS belonged maintained the second position, many of the CHHS math teachers who resisted change to performance-based instruction adhered to the sorting philosophy. These math teachers thought the solution to challenges some students had learning mathematics was the development of new courses geared to these students. Angus & Mirel (1999) reported “offering courses with academic titles, but unchallenging content, an educational bait and switch” was a common method of attempting to show reform. Most CHHS math teachers said the math department should provide such courses to accommodate the needs of struggling students. Many enjoyed being mathematics teachers; mathematics reigned with science as the discipline with “mind power.” Because some *resisters* believed only certain students were capable of learning higher levels of mathematics, they did not see the need to provide alternative approaches to academically rigorous courses (Clark, Meyers, Lloyd, Bennett, Miller).

The second question considered how teachers determined whether systemic changes to teaching had been made in their own practice and whether these changes had affected student performance. Most *reformers* stated their total perspective on teaching changed as they embraced reform. They contended that since times were changing, it was essential that education changed. They reported their teaching had been more interesting and exciting since they had incorporated performance-based modes. Many stated that just when their teaching was becoming boring, they had made changes that gave *life* to their work (Manuel, Feltis, Connelly, Rivera, Munro).

Those who had not implemented major changes in their teaching recognized their teaching had remained relatively unchanged over the years. *Resisters* taught in a style natural for them; they did not plan to make any major changes in their future teaching. In fact, some

teachers already felt overwhelmed with demands for Understanding by Design, performance-based techniques, culminating projects, and standardized state exams. They considered current demands impossible to meet; these teachers had the philosophy that “what worked for them should work for current students” (Bennett, Compton, Brown, Lloyd).

Whether or not teachers were interested in educational reform, teachers gauged the effectiveness of changes by student reaction and performance. Most teachers contended it was impossible to actually conduct any scientific studies with their own students; teachers were already overloaded and did not have time to do more than use student reactions and performance to measure success. Hence, all teachers used student feedback to gauge their effectiveness. They mentioned that today’s students made teachers aware of the strengths and weaknesses of their teaching. The extent to which teachers used this feedback varied from teacher to teacher; some *reformers* consistently used student input to modify their classes (Endrew, Brown, Rivera, Feltis, Monesco).

Because I was a CHHS math teacher during the research period, I participated in the reform opportunities that were available to CHHS teachers. I believe in belief and practice, I was a member of the *reform* group. As a result of my beliefs, experience, and training, I provided my students with presentation, activity, and project assessments. I tried to improve my own teaching as I attempted to be a constructive department member. I continued to study education research; I also investigated math developments from the last century and listened to student presentations that discussed mathematicians and their ideas. I encouraged others to participate in reform and, when they sought materials, I supplied resources and ideas to individuals and the group. I used activities and ideas that others presented. Realizing my enthusiasm for reform, I tempered my participation because I believed some members of the

department were tired of hearing about educational research and reform. However, my strong beliefs in necessary math reform prompted my consistent support for educational change in our department. The next section discusses conclusions of the study and relates them to the change indicators that were used.

Conclusions

In conclusion, differences existed that distinguished teachers willing to incorporate performance-based teaching and assessment in their educational practices in mathematics from those who were not interested. Teachers described themselves concerning whether or not they had made systemic changes in their teaching. Although they did not use the *reformer*, *resister* categories, the teachers provided reasons they either supported or resisted teaching changes. In this study, seven of the other eleven CHHS math teachers indicated they had no plans to make systemic changes to their teaching; they did not believe adding performance-based work was important in mathematics. Three of the math teachers showed promise in making significant changes in their teaching. These three mentioned they knew there were more effective ways of reaching all students. Also, they said they planned to use more projects when they found suitable ones; they showed interest in collaboration with others in searching for projects and activities. One of the three had a student teacher in the spring of 2004. Even though she thought things took too long with the student teacher directing them, this instructor saw promise in the student group work the student teacher used. She observed student oral presentations and recognized student need for communicating math ideas. Since these three teachers will affect the progress of the department, they, along with the two others who already embraced reform, may be catalysts for change in the math department.

Most CHHS math teachers exhibited what Dan Lortie (1975) described as *reflexive conservatism*, which is reliance on familiar routines. Many teachers thought they did not have the time, money, inclination, or energy to revise their mathematics teaching. Their views of teaching, learning, and mathematics had not changed significantly from when they were students. They enjoyed math. They did well in math. They could show students, who were willing to do their part, how to do well in math. Since most CHHS math teachers believed they were successful teachers, they did not plan to make significant changes in their teaching.

The teacher change indicators from Chapter Three provide insight into the CHHS change scenario. Each is discussed next; it is important to keep in mind that some *resisters* and *reformers* offered ideas that suggested intermediary positions for issues. However, in general, *reformers* demonstrated the indicators in theory and practice.

Change Indicator One: The teacher's ontology reflected a shift in the view of mathematics to include more than the general definition of a deductive/inductive system.

The ontologies of math teachers confirmed that most *resisters* considered high school mathematics as a consistent, relatively unchanging body of knowledge, skills, and techniques. Because they viewed high school mathematical content as constant, the *resisters* believed their own math knowledge was sufficient for their teaching. While the *reformers* used descriptive words like "fascinating, exciting, and beautiful" to describe mathematics, the *resisters* used nouns like "definitions, laws, structure, and language."

Change Indicator Two: The teacher's epistemology displayed familiarity with current educational philosophies.

Teacher epistemologies varied greatly: Often *resisters* suggested devising new courses aimed at those for whom math was a challenge while *reformers* encouraged changing existing

college preparation classes to forums in which recent mathematics could be investigated and discussed. Mentioning their own successes in learning, *resisters* employed didactic teaching methods as their main educational strategies. These teachers noted making efficient use of class time prompted them to design discussions, lectures, and notes that facilitated student learning. *Resisters* believed student weaknesses and challenges explained student failures; these teachers considered most educational problems beyond teacher capabilities to correct. *Reformers* suggested that constructivist approaches using performance-based materials and discussion provided teachers with necessary assistance to teach all students. Although these teachers discussed the challenges some students have, they believed teachers are required to provide the best possible learning environment—to do what they can to enhance learning opportunities for all students. *Reformers* thought incorporating performance-based work in mathematics enriched teaching and learning.

Change Indicator Three: The teacher’s practice included a variety of student assessment and assignment options.

Teacher practices varied from traditional “review, present, practice” ideas to open-ended assessments providing context for mathematics for each unit of instruction. Most teachers said they used a variety of materials, but *reformers* provided evidence, by giving descriptive information about projects and activities they used. Even though some *resisters* insisted their teaching fostered student conceptual understanding, their practice verified learning was teacher-centered and teacher-directed; communication among students was limited.

Change Indicator Four: The environment of the teacher’s class provided numerous opportunities for active learning for students.

Reformers verified they provided opportunities for active learning to their students by describing activities and projects they used in their teaching and assessment. When *reformers* were observed, they engaged their students in a variety of active learning options. Often, *resisters* noted they did not have time to find and use active learning modes. Some *resisters* believed their training and education qualified them to be experts in the classroom; they thought that relying on more active student learning mollified some students, but did not improve learning. Some *resisters* considered performance-based work “fun and games;” certain *reformers* mentioned that other teachers accused them of using projects only because they wanted students to enjoy math.

Change Indicator Five: The teacher frequently and enthusiastically shared educational ideas and investigations with others in the department and/or school.

Resisters visited with other teachers about their teaching. In general, they did not seek ideas and activities outside their immediate physical teaching area. A few *resisters* used internet access to search for activities. *Reformers* consistently shared teaching ideas and active learning materials with others. These teachers used educational materials obtained through their professional organizations and publications. Many *reformers* presented sample teaching lessons and workshops for teachers at professional meetings. Although no formal mention of the term, *learning communities*, was made in this study, *reformers* verified their importance in successful implementation of reform. *Reformers* consistently reported the significance of networking with others who promoted change.

Change Indicator Six: The teacher’s attitude toward student learning, teacher learning, and teaching was positive.

Some *resisters* commented that their teaching did not change much and that they had a teaching routine that worked for them. A few suggested they taught because the job provided a stable income for them, and they liked students and student activities. In describing their teaching, many provided evidence they had teaching down to a routine. Some expressed frustration with teaching students who did not appear interested in learning. *Resisters* were organized; they had files of worksheets, quizzes, and exams they used with a particular text. On the other hand, *reformers* discussed projects and activities they enjoyed using and successful changes they had made in materials. They showed enthusiasm by their responses, facial expressions, and mannerisms. Students who had difficulties with learning mathematics challenged them; these teachers continued seeking methods and materials that prompted conceptual understanding for all students.

Change Indicator Seven: The teacher showed interest in educational research about theory and practice by reading and discussing current literature on mathematics and education.

Teachers displayed the most variation with this indicator. Opinions about research in education ranged from *resister* insistence that educational research was flawed, unimportant, or superfluous to *reformer* declarations that educational research was essential for professionalism. Few *resisters* or *reformers* discussed mathematical research; in believing mathematics does not change, *resisters* discounted the important of math research. With regard to mathematical research, there were *resister* and *reformer* exceptions: a few participants recounted the mathematical studies they read; some shared recent math developments with their students.

Change Indicator Eight: The teacher displayed a profound understanding of mathematics.

Most math teachers in this study had mathematics training that made them qualified under the *No Child Left Behind* (2001) criteria. In general, few *resisters* or *reformers* mentioned

mathematics outside their current teaching assignments. As far as demonstrating a profound understanding of mathematics, teachers were unable to verify this indicator in this limited study.

An indicator that I did not separate from the others was teacher awareness of changes in mathematics over the last century. Because this indicator was embedded in Indicator Seven, I was unable to discover much about *resister* and *reformer* ideas about recent mathematical studies.

Implications

This study confirmed that mandated changes imposed from “above” rarely produce significant reform in a school setting. Although their school was involved in change to a performance-based mode of instruction, most CHHS math teachers resisted making substantive changes to their math teaching. Generally, these teachers said they did not change in any systemic way because they did not perceive a need for change and/or because they did not plan to add anything to their already busy work hours. On the other hand, because some change advocates suggest a ten per cent change each year is optimal (Rivera, personal interview and survey 7/29/03), there is promise of reform in the math department as math teachers collaborate to set learning goals and requirements for each course. In order to avoid “becoming a nation divided both economically and racially by knowledge of mathematics” (NRC & MSEB, 1989), CHHS may benefit from implementing strategies for promoting math reform. As documented in the literature review, one important change component is professional development for teachers.

The CHHS math department may find ways to encourage all math teachers to participate in discussion. As learning communities are developing in the school, there are opportunities for more educational dialogue in the building. Because teachers recognized some students who passed certain courses really did not know and understand the material, the math teachers were

interested in finding more effective methods. Hence, teachers may be motivated to incorporate reform ideas in their work. With an emphasis on successful math achievement for all students, CHHS math teachers may look to other departments for strategies. Since other departments provided performance-based projects and problems that students extended to become culminating projects, the math department may begin finding math areas that could extend student interest. In looking for these areas and their associated problems, teachers consider using more assessments for which there are no “set” answers. As fulfilling requirements for culminating projects and state testing becomes part of graduation requirements, teachers may find techniques that enhance student learning for all. Since collaboration is a complex issue, math teachers will need support as they attempt to balance their needs for individuality with their efforts at collaboration (Nolan & Meister, 2000).

The current math department chair, Jeff Meadows, recognizes the benefits of teacher observations of other teachers. Beginning with the 2004-2005 school year, Meadows paired each math teacher with a partner who teaches the same course. These pairs are expected to observe each other and discuss their teaching. Some promising dialogues and changes may be prompted by these teaching exchanges, especially if research is used to provide direction to the observations. Since the department is involved in an overall reform project, the math teachers will be expected to participate in innovation. With a new principal and one other new administrator at CHHS, new approaches and changes will be expected.

Observing teachers in other departments and viewing new teaching techniques may promote innovation in math teaching, again if research provides structure to the observations. If math teachers at CHHS are dissatisfied with current student performance levels, the teachers may incorporate new teaching modes. The fact that fifty out of fifty calculus students

consistently pass the AP exam indicates that some students demonstrate successful math development. Making math achievement for all a priority may spearhead the change process for CHHS.

Another important factor in constructive change is the enthusiasm teachers have for their profession. As noted earlier, studies of teacher change to performance-based techniques document the fact that change often motivates teachers and revitalizes their careers. Further interest in math reform may rejuvenate the math department at CHHS. Also, there is the possibility that the example of individual teachers will influence others in the department and encourage them to try some new teaching techniques. As CHHS teachers in other disciplinary areas use performance-based teaching techniques, math teachers may feel urgency to adopt similar methods. Part of the change may be in response to student comments. Today's students are informed about learning styles; when they are bored, the teacher hears about it.

One activity that may encourage reform support from math teachers at CHHS is more departmental involvement with NCTM and other professional groups. Because NCTM has fostered educational math reform for many years, their activities, projects, and articles provide constructivist perspectives on teaching mathematics. In some non-threatening way, the math teachers who belong to professional organizations could provide information to other teachers. Discussing *PSSM* may encourage some math teachers to reflect upon their own epistemological and ontological views. Frykholm (1999) reported that some teachers viewed the *Standards* as “content to be learned rather than philosophy to be adopted.” It may be beneficial for CHHS math teachers to discuss the implications of that statement. In department meetings, the chair might model active learning modes by involving teachers in situations in which they are learners. In this way, he may generate discussions that center on learning and teaching. By using their

imaginings and observing other teachers doing the same, teachers may be willing to try new ideas. Also, presentations that involve math teachers in activities that use the constructivist approach may foster change. For example, knot theory is a relatively new secondary topic that seems to interest many, and has ties to genetics. Participating in appropriate activities in which they explore knot theory concepts may encourage teachers to discuss the essence of mathematics and its teaching. If the teachers become learners again and enjoy the experience, they may be willing to incorporate ideas into their teaching. Schifter and Fosnot (1993, 1996) found that teachers needed to have opportunities to learn mathematics in ways that parallel those they are expected to use.

Also, encouraging other departments to work with the math department may benefit both groups. In observing teachers in other disciplinary areas, I noted classroom atmosphere was more relaxed in those rooms. Students in classes other than math appeared eager to give their opinions about the topic being discussed. In math classes, there seemed to be a limiting, rigid feeling about both participation and time allotment. Since the math department has a reputation for being resistant to change, this collaboration might provide a positive image change for math teachers.

Finally, with more sharing of teaching and assessment ideas in the department, teachers may not be reluctant to try new ideas. The CHHS math teachers respect the diversity and ability that exist in the department. One of the most promising parts of this study was the discovery that all CHHS math teachers believed the department consisted of a phenomenal group of qualified individuals. Making use of the potential of the group is a challenge for the future. By respecting the opinions of all department members and negotiating the challenges diversity of opinion

presents, CHHS teachers may develop a change scenario that will work for all. In this way, teachers may move toward constructivist views and approaches in their teaching.

As in any investigation, this research suggested ideas for further studies into teacher change to performance-based learning and assessment in mathematics. The next section provides suggestions for extensions to this research.

Further Research

An important source of projects and activities that employ a performance-based approach to mathematics is suggested. Many teachers resist change to constructivist approaches because they lack appropriate materials. Although considerable resources are available, an updated resource source with associated research comparing the effectiveness and usefulness of various performance-based activities and projects would be helpful.

Inquiry into why some students choose to remain uninvolved in math work may be beneficial. Since many teachers think it is *more* difficult to *not* participate in homework and class discussions than to become involved, research into why students choose to “do nothing” is recommended. Parallel consideration of why some teachers don’t become involved in systemic reform may be informative. Along the same lines, research on why students don’t do assignments would be valuable; this research could be tied to performance-based methods to see whether students are willing to do certain types of work more than other kinds.

Research about the views of society and their effects on math education have merit. CHHS math teachers have not involved parents in any significant way in daily math teaching. Studies that provide parental involvement techniques and their implications would be useful.

Further investigations about teacher interest in recent math developments and its effect of their willingness to incorporate performance-based work in their teaching are important to

consider. Because this issue was embedded in Teacher Indicator Seven, no significant findings were available in this study.

Studies investigating whether or not teacher image, as perceived by others, is a factor in implementing performance-based modes offer opportunities. It would be interesting to know whether or not reputation with students or other teachers influences teacher change to performance-based work.

Because I assumed math teachers used technology, I did not investigate whether or not its use affected teacher willingness to use performance-based work. In interviewing, surveying, and observing teachers, I discovered some teachers did not consistently use technology. Hence, studies of use of technology and its effect on teacher willingness to change to performance-based instruction would be beneficial. Also, I prefer math classrooms with tables. I appreciate rooms with adequate shelves and closets so that manipulatives, math books, models, and other materials are readily available. My ideal math classroom resembles a typical science room—a laboratory for investigating mathematics. A math lab room makes performance-based work easier for me to implement. Hence, research about the effects of the physical environment on implementation of performance-based models would be valuable.

Some characteristics that were not studied appeared to be non-factors in this study. Teacher age, experience, and gender did not seem to affect a teacher's willingness to incorporate performance-based work. Also, whether teachers had mathematics or education majors did not appear to influence teacher reform tendencies. Actual research that considered these teacher differences may provide valuable information. Finally, other studies that document how some educators move to more active teaching approaches could provide further insight into

educational reform. As more teachers who have not been involved in reform are encouraged to participate, implementation suggestions remain valuable.

Hiebert et al. (1997) delineated five dimensions essential for classrooms that promote understanding: nature of classroom tasks; role of the teacher; social culture of the classroom; mathematical tools as learning supports; and equity and accessibility. Teachers control or greatly influence all five factors; hence, teacher change becomes crucial in implementing reform that promotes understanding. With our ever-changing economy and world, changes we can't imagine will affect educational progress in future years. Few educators advocate change for the sake of change. Teachers realize they are one component in the learning system; however, most recognize the importance of their part. Although teachers cannot correct all learning challenges with their work, they can attempt to ensure their contribution encourages learning for all students. Adjusting teacher attitudes, philosophies, professional knowledge, and skills to support increased success for students and revitalized personal involvement enhances math teaching, learning, and assessment. In order to be effective, change must correct some of the failures in current educational systems. Inclusion of performance-based work in mathematics offers improvement opportunities for teachers and learners alike. Davis (1996) suggested

designing learning experiences that meet the needs of students, and understanding more deeply what is involved in the way humans think about mathematics, may indeed be seen as intimately related.

Exploring this idea provides opportunities for educational insights in the math reform process. Vygotsky's belief that "the only good teaching is that which outpaces development" encourages teachers to monitor their teaching. Bravo to those ready to meet new challenges and

provide students with opportunities to make progress in their educational growth, while sustaining personal growth and enthusiasm.

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APPENDIXES

APPENDIX A
SURVEY INSTRUMENT

EDUCATIONAL SURVEY

1. During the majority of class time, my students play initiating or active roles in the lesson.

Strongly agree Agree Disagree Strongly disagree

Different from my earlier teaching Same as my previous teaching

Encouraged by my district/school Not encouraged by my district/school

Explain why or why not:

2. In each lesson, students make connections between the math we study and the world around us.

Strongly agree Agree Disagree Strongly disagree

Different from my earlier teaching Same as my previous teaching

Encouraged by my district/school Not encouraged by my district/school

Explain why or why not:

3. I devote significant time in each lesson for student-student discussion.

Strongly agree Agree Disagree Strongly disagree

Different from my earlier teaching Same as my previous teaching

Encouraged by my district/school Not encouraged by my district/school

Comments:

4. I devote significant time in each class for student-teacher discussion.

Strongly agree Agree Disagree Strongly disagree

Different from my earlier teaching Same as my previous teaching

Encouraged by district/school Not encouraged by my district/school

Comments:

5. I use regular formal and informal assessments to monitor student progress.

Strongly agree Agree Disagree Strongly disagree

Different from my earlier teaching Same as my previous teaching

Encouraged by my district/school Not encouraged by my district/school

Comments:

6. I consistently reflect on and collect information about my own instructional practice in order to consider changes and improvements.

Strongly agree Agree Disagree Strongly disagree

Different from my earlier teaching Same as my previous teaching

Encouraged by my district/school Not encouraged by my district/school

Comments:

7. We study problems for which a range of answers is acceptable.

Strongly agree Agree Disagree Strongly disagree

Different from my earlier teaching Same as my previous teaching

Encouraged by my district/school Not encouraged by my district/school

Comments:

For the following, give any response that you would like to make:

1. Pure mathematics is clean, while applied mathematics is “messy.”

2. Some people are good at math, while others are not—you either have it or you don’t.

3. I have found past professional development experiences to be useful and have incorporated many ideas into my instructional practice.

4. The most important requirement for a math teacher is that the teacher explains well.

5. Research in education is as important as research in mathematics.

Number of years that you have worked in education:

Your general job description and disciplinary area:

Highest degree that you have earned:

APPENDIX B
INTERVIEW QUESTIONS FOR ADULTS

FACTORS AFFECTING IMPLEMENTATION OF A PERFORMANCE-BASED LEARNING
AND ASSESSMENT MODEL IN HIGH SCHOOL MATHEMATICS

INTERVIEW QUESTIONS—open-ended with encouragement to add comments

1. Please tell me about you—your position and work.
2. What do you feel are your strongest qualities as a teacher? How does your personality influence your teaching? How do your experiences as a student affect your teaching?
3. Have you felt pressured to change your teaching lately? What prompts you to make changes in your teaching? Are there factors that make change difficult or challenging? Are there factors that encourage you to make changes? How do you evaluate whether or not your teaching changes are beneficial to student learning?
4. Do you use projects in your teaching? Do you use activities? Describe one of your favorite lessons.
5. Could your current teaching be described as using performance-based techniques? Please explain your answer.
6. To what extent do you work with others in your math teaching?
7. What is mathematics? Does mathematics change over the years?
8. How do people learn mathematics? What do you think are successful teaching strategies and techniques in math.
9. Do you use educational research in your teaching? Please comment on your response. Do you use research in mathematics in your teaching? Comment.

APPENDIX C
INTERVIEW QUESTIONS FOR STUDENTS

FACTORS AFFECTING IMPLEMENTATION OF A PERFORMANCE-BASED LEARNING
AND ASSESSMENT MODEL IN HIGH SCHOOL MATHEMATICS

STUDENT INTERVIEW QUESTIONS—open-ended with encouragement to add comments

1. Tell me a little about you—what you are doing now and what you've done in the past.
2. Have you noticed any changes in your education as the years have gone by?
3. Do you see any recent changes in the way your teachers teach? Explain.
4. Have you noticed any differences in the way mathematics is taught? Explain.
5. If you could change a few things about the way teachers teach mathematics, what would they be and why?
6. Do you think your math teachers are still learning? Explain.
7. Do the math teachers at this school use performance-based techniques? Explain.
8. Do you know the ways in which you best learn something?
9. Do you think you are being asked to change the way you learn?
10. How do you feel about change, in general?
11. At your school, does the math department work together?
12. What is mathematics? Do you think it stays constant?
13. How do you think people learn mathematics?

APPENDIX D
TEACHER OBSERVATION FORM

CLASSROOM OBSERVATION FORM

Date:

School:

Time	Activity	Comments

1. Teacher's ontology reflects an enlargement of the view of mathematics.

Strongly agree Agree Disagree Strongly disagree

Comments:

2. Teacher's epistemology displays a familiarity with current educational philosophies.

Strongly agree Agree Disagree Strongly disagree

Comments:

3. Teacher's practice includes a variety of student assessment and assignment options.

Strongly agree Agree Disagree Strongly disagree

Comments:

4. Environment of the class includes opportunities for active learning for students.

Strongly agree Agree Disagree Strongly disagree

Comments:

5. Teacher shares educational ideas and investigations with others in the department/school.

Strongly agree

Agree

Disagree

Strongly disagree

Comments:

6. Teacher shows interest in educational research about teaching/learning mathematics.

Strongly agree

Agree

Disagree

Strongly disagree

Comments:

7. Teacher displays a profound understanding of mathematics.

Strongly agree

Agree

Disagree

Strongly disagree

Comments:

APPENDIX E
INFORMATION ON RESEARCH PARTICIPANTS

INFORMATION ON RESEARCH PARTICIPANTS

NAME	LOCATION	IDENTIFIER	REF OR RES
Dan Bennett	CHHS	Teacher	RES
Marie Brown	CHHS	Teacher	REF-RES
William Buck	CHHS	Teacher	RES
Patrick Clark	CHHS	Teacher	REF-RES
Martin Compton	CHHS	Teacher	RES
Jim Endrew	CHHS	Teacher	REF
Jill Jones	CHHS	Teacher	REF-RES
Henry Lloyd	CHHS	Teacher	RES
Jeff Meadows	CHHS	Teacher	REF-RES
Sue Meyers	CHHS	Teacher	REF-RES
Drew Miller	CHHS	Teacher	REF-RES
Don Blakeley	CHHS	Administrator	REF
Will Corwayson	CHHS	Administrator	REF
Alek	CHHS	Student	
Ashley	CHHS	Student	
Charlotte	CHHS	Student	
Marty	CHHS	Student	
Meredith	CHHS	Student	
Sam	CHHS	Student	
Nancy Beckwith	District	Supervisor	REF
Seth Connelly	Another state	Teacher	REF
Angie Feltis	Another state	Teacher	REF
Amy Hansen	West View	Teacher	REF
Vicki Hemple	West View	Teacher	REF
Marie Manuel	Another state	Teacher	REF
Lindsey Monesco	Helenmont	Teacher	REF
Julie Munro	West View	Teacher	REF
Rita Rivera	Another state	Teacher	REF
Pete Sommers	Another state	College professor	REF
Cindy Thompson	District	Teacher	REF
Kalie Ward	Helenmont	Teacher	REF-RES
Dave Winters	Another state	College professor	REF

REF indicates reformer; RES indicates resister. Those difficult to categorize were given two labels the first one reported their desired category; the second one reflected their practice. In cases in which no direct teaching observations were made, the category was determined from teacher interviews and surveys. This self-reporting may not be accurate.