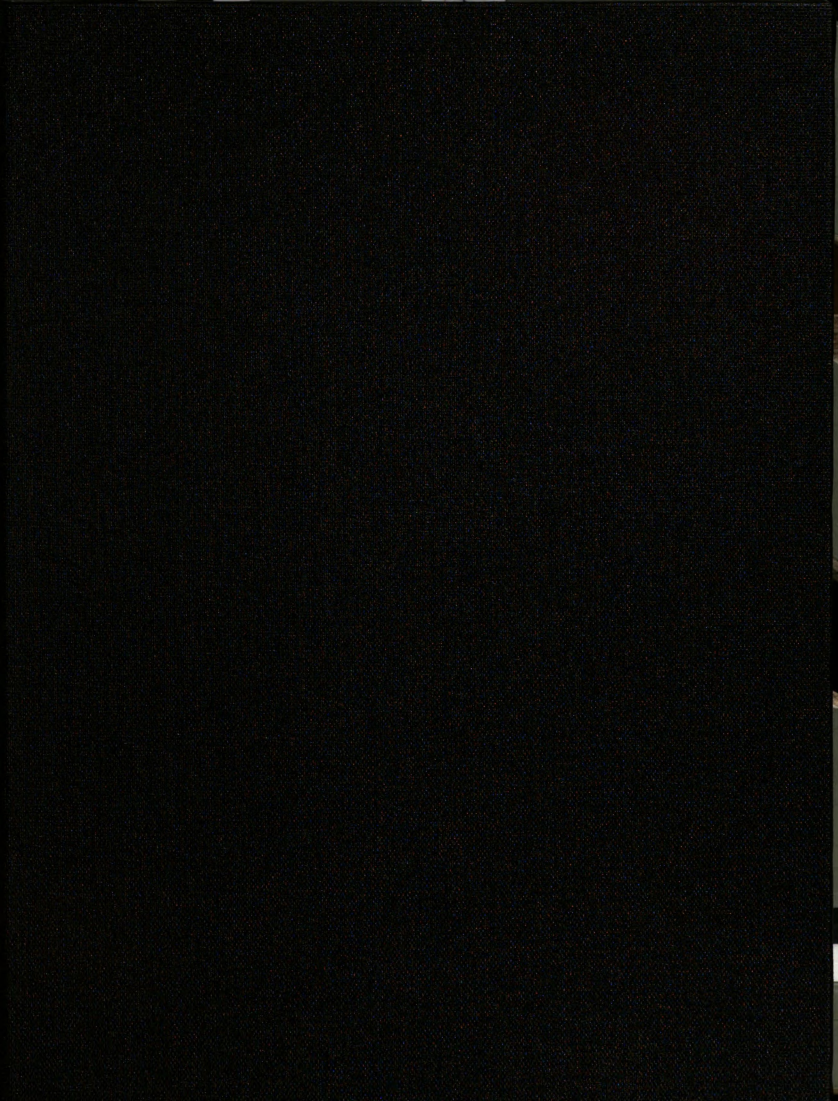




THESIS



This is to certify that the

dissertation entitled

TEACHERS' KNOWLEDGE AND BELIEFS
ABOUT THE USE OF COMPUTERS
IN HIGH SCHOOL MATHEMATICS

presented by

Clifford Orindu Akujobi

has been accepted towards fulfillment
of the requirements for

Ph.D. degree in Educational Systems
Development

A handwritten signature in cursive script, reading "Ralph T. Putnam".

Ralph T. Putnam

Major professor

Date March 31, 1995

LIBRARY
Michigan State
University

PLACE IN RETURN BOX to remove this checkout from your record.
TO AVOID FINES return on or before date due.

DATE DUE	DATE DUE	DATE DUE
FEB 05 1997		
MAR 08 1997		

**TEACHERS' KNOWLEDGE AND BELIEFS ABOUT THE USE OF COMPUTERS
IN HIGH SCHOOL MATHEMATICS**

By

Clifford Orindu Akujobi

A DISSERTATION

**Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of**

DOCTOR OF PHILOSOPHY

**Department of Counseling, Educational Psychology
and Special Education**

1995

ABSTRACT

TEACHERS' KNOWLEDGE AND BELIEFS ABOUT THE USE OF COMPUTERS IN HIGH SCHOOL MATHEMATICS

By

Clifford Orindu Akujobi

The study examined in what ways and to what extent teachers' knowledge and beliefs about teaching and learning mathematics influence the use of educational technology, especially the use of computers for mathematics instruction. Six teachers were interviewed and their classrooms were observed. Employing qualitative research methods, this investigation provided an opportunity for deeper and better understanding of teachers' perceptions of what they know, believe, and report about the role of computers in mathematics instruction; and their views about its future adoption in the classroom.

It was found that the teachers' knowledge of and beliefs about the use of educational technology to teach mathematics could be conceptualized and

described along two major knowledge clusters: conceptual and didactic (narrow). Analyses of the two clusters showed that teachers who held conceptual views about mathematics taught mathematics in alternative ways and supported the use of technology for instruction. In contrast, teachers who viewed mathematics as a set of rules and procedures tended to avoid using technology and envisioned its use narrowly--for remedial purposes and drill-and-practice. Interpretation of these views called attention to three factors that influenced the teachers: their knowledge and educational goals about mathematics, their beliefs about teaching and learning of mathematics, and their perceptions about the potential role of educational technology in mathematics instruction.

One major implication for further research and practice is how to confront teachers' knowledge and beliefs about the use of educational technology in teaching high school mathematics. The information provided in this study may be useful to education reformers, curriculum developers and policy makers who are advocating better ways of creating better learning environments for mathematics learning.

Copyright by

Clifford Orindu Akujobi

1995

DEDICATION

To the memory of my late parents:
Humphrey Anokwuru Akujobi and Kezaih Ogazi Akujobi,
for laying the foundations of ambitions
and providing me the love of learning.

To my wife, Vesta,
and our sons, Nnadozie, Obinna, and Nnaemeka,
for their sacrifices, patience, love, and support.

ACKNOWLEDGMENTS

I wish to express my profound gratitude to Dr. Ralph T. Putnam, my dissertation chair and chairman of the doctoral committee, for his invaluable insights into the nature of teachers' knowledge and beliefs, his dependable professional guidance and advice, and his patience and personal concern.

To my advisory and dissertation committee members, Drs. Joe Byers, James Gallagher, and Leighton Price: Thank you for your guidance, many learning experiences and valuable advice during my doctoral program at Michigan State University.

Special gratitude to the teachers who participated in this study, for their cooperation and openness to being observed and interviewed.

Special gratitude to my many friends and colleagues for their confidence and support. Special thanks to Barbara Reeves for final typing and formatting of the dissertation.

Finally, I thank my brothers and sisters for their understanding, confidence and support throughout my collegiate and graduate carrier.

TABLE OF CONTENTS

<u>CHAPTER</u>	<u>PAGE</u>
I. INTRODUCTION	1
The Purpose of Study	4
Conceptual Framework	5
Need for Teachers' Knowledge and Beliefs as a Conceptual Framework	8
Research Questions	11
Assumptions & Clarifications	11
Overview of this Document	13
II. REVIEW OF RELEVANT LITERATURE	14
Overview	14
The Role of Computers in Mathematics Instruction	
Social Rationale: Children Should Be Prepared to Face the Challenges of the Information Age	15
Pedagogical Rationale: Computers Improve the Instructional Processes and Learning Outcomes	16
Teachers' Knowledge and Beliefs	22
Teachers' Knowledge and Beliefs about Educational Technology	24
Teachers' Knowledge and Beliefs about Mathematics, Teaching, and Learning	30
Teachers' knowledge and beliefs about mathematics	31
Teachers' knowledge and beliefs about teaching mathematics	36
Teachers' knowledge and beliefs about learning and learners	39
Teachers' conceptions about classroom management and student interaction	43
Summary	48

III.	METHODOLOGY	49
	Overview	49
	Rationale for Use of Qualitative Research	50
	Site	52
	Teacher Selection	54
	Data Collection	56
	Data Analysis	60
	Limitations	63
IV.	TEACHER PROFILES	65
	Overview	65
	Vesta	66
	Educational Goal	66
	Conceptions of Teaching Mathematics	67
	Conceptions of Using Technology for Mathematics	
	Instruction	69
	Conceptions of Students: Beliefs about Performance/	
	Behavior and Classroom Discourse	70
	Teacher as Proactive, Working to Improve Learning	72
	Teacher Open to New Ideas	73
	Views on Teachers' Resistance to Instruction Technology	74
	Summary of Vesta's Views	76
	Tomia	76
	Teaching Context	76
	Educational Goal	77
	Conceptions of Teaching Mathematics	78
	Conceptions of Using Technology for Mathematics	
	Instruction	81
	Conceptions of Students' Interaction and Classroom	
	Management	84
	Teacher as Proactive, Working to Improve Learning	85
	Teacher Open to New Ideas	86
	Views on Teachers' Resistance to Instruction Technology	86
	Lack of knowledge and beliefs	86
	Lack of time	87
	Lack of funds and resources	88
	Summary of Tomia's Views	89
	Robinson	91
	Teaching Context	92
	Educational Goal	92
	Conceptions of Teaching Mathematics	93
	Conceptions of Using Technology for Mathematics	
	Instruction	95
	Conceptions about Learning	97
	Teacher Being Reactive, Working to Survive	99

	Teacher as Being Rigid	100
	Summary of Robinson's Views	101
Bebe		103
	Teaching Context	103
	Educational Goals	104
	Conceptions of Teaching Mathematics	105
	Conceptions of Using Technology for Mathematics	
	Instruction	107
	Conceptions about Student Learning	108
	Teacher Being Proactive, Working to Improve	
	Learning	110
	Summary of Bebe's Views	111
Kayce		113
	Teaching Context	114
	Educational Goals	114
	Conceptions of Teaching Mathematics	115
	Conceptions of Using Technology for Mathematics	
	Instruction	117
	Conceptions of Learning	118
	Teacher as Reactive, Working to Survive	120
	Teacher as Being Rigid	120
	Summary of Kayce's Views	121
Obed		123
	Conceptions of Teaching Mathematics	124
	Conceptions of Using Technology for Mathematics	
	Instruction	125
	Conceptions of Why Teachers Do not Use Computers	
	for Instruction	126
	Summary of Obed's Views	128

V. FINDINGS ACROSS TEACHERS 131

Research Question 1A: What Do Teachers Know and Believe	
about Teaching and Learning Mathematics?	134
Teachers' Conceptions about Mathematics	134
Vesta	135
Tomia	135
Obed	135
Kayce	136
Robinson	136
Bebe	136
Summary of teachers' conceptions of mathematics	136
Teachers' Conceptions about Teaching and Learning	
Mathematics	136
Vesta	138
Tomia	138
Obed	138

Bebe	139
Robinson	140
Kayce	141
Summary of teachers' conceptions of teaching and learning	142
Teachers' Conceptions about Students	142
Summary of teachers' conceptions of students	145
Research Question 1B: What Do Teachers Know and Believe about the Potential Role of Computers in Teaching and Learning Mathematics?	146
Vesta	148
Tomia	149
Obed	150
Bebe	151
Kayce	152
Robinson	153
Summary of Responses to Question 1B	155
Research Question 1	157
Important Emerging Findings	157
General Reflections on Main Research Question	162
Research Question 2	163
Accessibility	164
Classroom Arrangement and Scheduling	165
Training	165
Time	166
Curriculum	167
Discretion Versus Direction	168
Context and Other Intangible Issues	170
 VI. SUMMARY, IMPLICATIONS, AND CONCLUSIONS	 172
Implications for Practice	174
Issues for Further Research	181
Conclusion	182
 APPENDICES	 184
Appendix A: Primary Interview Questions	184
Appendix B: Pre-Observation Interview	190
Appendix C: Observation Form	192
Appendix D: Post Observation Questions	194
Appendix E: Teachers' Knowledge and Beliefs about the Use of Computers in High School Mathematics	196
 REFERENCES	 198

LIST OF TABLES

<u>TABLE</u>	<u>PAGE</u>
1 General Categories for Analysis	62
2 Summary of Vesta's Views	74
3 Summary of Tomia's Views	89
4 Summary of Robinson's Views	101
5 Summary of Bebe's Views	112
6 Summary of Kayce's Views	121
7 Summary of Obed's Views	128
8 Teachers' Conceptions Matrix	132

LIST OF FIGURES

<u>FIGURE</u>		<u>PAGE</u>
1	Conceptual Framework	7
2a	Method of Investigation	57
2b	Method of Investigation	58

CHAPTER ONE

INTRODUCTION

In recent years there have been increasing demands for educational reform in many countries, especially in mathematics and science education. Reformers argue that most educational systems can no longer support economic competitiveness needed in an increasingly interdependent world marketplace (Plomp & Pelgrum, 1993). Mathematics (as well as science) is important in nation building and has been recognized as a tool that, when done successfully, empowers individuals with useful skills for successful thinking and performance in society and for self-fulfillment (National Council of Teachers of Mathematics, 1989, 1991; National Research Council, 1989; Putnam et al., 1989).

In the United States, there is also an increasing concern about students' poor performance in mathematics. A number of national surveys (Dossey, Mullis, Lindquist, & Chambers, 1988) show that, although students in the U.S. have mastered simple arithmetic facts, only a small percentage are capable of complex, multi-step reasoning in mathematics. This concern, along with national concerns regarding the shortage of students in advanced mathematics classes, has coincided with educators' attempts to change the focus of mathematics curriculum and teaching (see NCTM, 1989, 1991; & NRC, 1989).

The calls made for major reform in mathematics education, notably those by the (NCTM, 1989, 1991) and the (NRC, 1989) point to a need for an increasingly mathematically literate society and the need to educate all students. NCTM has argued that educating all students will require the creation of new curriculum, instructional practices, and classroom environments. These new classroom environments should support teachers and students in making connections between mathematical and scientific concepts and human problems and could be very different from much current classroom practice. The image of mathematics teaching needed includes, among other things, secondary teachers who are proficient in using and helping students utilize computer and other technological tools to explore and pursue mathematical investigations, (NCTM, 1991).

In response to the demands of creating new classrooms that support meaningful learning in schools, concentrated efforts in educational technology and instructional design have been made in introducing different instructional strategies to improve mathematics instruction. For example, a growing body of research has presented reasons supporting the introduction of computers in schools (see Ganguli, 1990; Hawkrigde, 1990; Sheingold, 1992; Thornburg, 1992). In reviewing technology and mathematics education, Kaput (1992) mentioned the important roles of computer for instruction, especially in mathematics. Kaput explained in detail the prospect and usefulness of computers as tools for mathematics instruction. For example, he compared dynamic versus static media.

When one writes an algebraic expression or draws a diagram, it just sits there, in a fixed state as written or drawn. Any variation needs to be projected onto it by the reader, or interpreter. One very important aspect of mathematical thinking is the

abstraction of invariance. But, of course, to recognize invariance - to see what stays the same - one must have variation. Dynamic media inherently make variation easier to achieve (p.525).

Kulik, Bangert, and Williams (1983) indicated that the use of computer-assisted instruction (CAI) has positive outcomes on learning and attitude. These positive outcomes were presented in Thornburg's (1992) report to the Council of Chief State School Officers. The report emphasized the usefulness and creativity of educational technology as a powerful tool that can help students understand mathematical functions through a variety of learning styles.

Despite the concentrated efforts of researchers in educational technology to support the use of computers as instructional tools in expressing mathematical ideas, and recording and analyzing information, little or no change has occurred in the way computers are used in most high schools for instruction (O'Connor, 1992). Though data suggest that technology holds much potential for facilitating creative learning environments, most classrooms have not changed from routine computation to teaching for understanding and problem solving. O'Connor claimed that teaching-learning processes have not improved because teaching style and classroom environment have not changed.

Even after a decade of concerted efforts to integrate technology into instruction, classrooms today resemble those of 50 to 100 years ago much more closely than today's assembly plants (p.54).

Past failures to produce substantive changes in the use of technology in teaching mathematics through similar efforts suggest that something important in the change process has been overlooked.

One area that has received scant research attention is what teachers know and believe about the use of technology in mathematics teaching. Computers

offer powerful and flexible ways of representing mathematical ideas that simply have not been available with other media. But to make use of these rapidly changing technologies, teachers need to be flexible and responsive in using educational technology tools in creative ways for teaching of mathematics. Yet we know little about what teachers know and believe about using this technology for mathematics instruction, or about how teachers use computers to teach mathematics. Therefore, this study explores how teachers' knowledge and beliefs about mathematics influence their use of educational technology for instruction.

Purpose of Study

The purpose of this study is to gain a deeper and better understanding of why computers are not frequently used in teaching and learning high school mathematics. In achieving this goal, the study explored the relationships among teachers' knowledge and beliefs about mathematics, teaching and learning of mathematics, classroom management and student interaction, and the potential role of computers in instructional computing. The exploration of the relationship between teachers' knowledge and beliefs about educational technology and teaching/learning of mathematics is important because it provided insights on how teachers' knowledge and beliefs about technology impacts its use in the classroom. In examining the relationships between teachers' knowledge and beliefs about educational technology and its role in teaching mathematics, a conceptual framework that articulates teachers' perceptions about the role of computers for mathematics instruction was constructed. The framework provided an opportunity to listen to what teachers say they know about mathematics, teaching and learning of mathematics, and computer technologies; and also to observe how mathematics teachers are

currently using computers in their classrooms. In doing this, I will discuss in detail the difficulties teachers face while using computer for teaching and learning of mathematics and its impact on classroom management and students interactions.

Conceptual Framework

Before the research questions to be addressed in this study are presented, a conceptual framework for the study will be discussed. The conceptual framework (see Figure 1) was developed for this study to present a view of the interaction between teachers' knowledge and beliefs about mathematics, teaching, learning, technology, classroom management and students' interaction, and other complex external factors that shape teachers use of technology in high school mathematics classroom. The study focuses only on the relationship between teachers' knowledge about mathematics, teaching, learning, technology, classroom management and students' interaction, and what and how they use technology in classroom. However, the framework represents other complex factors such as the context, school milieu, and other intangible factors that interact with teachers' thinking in order to perform their duties.

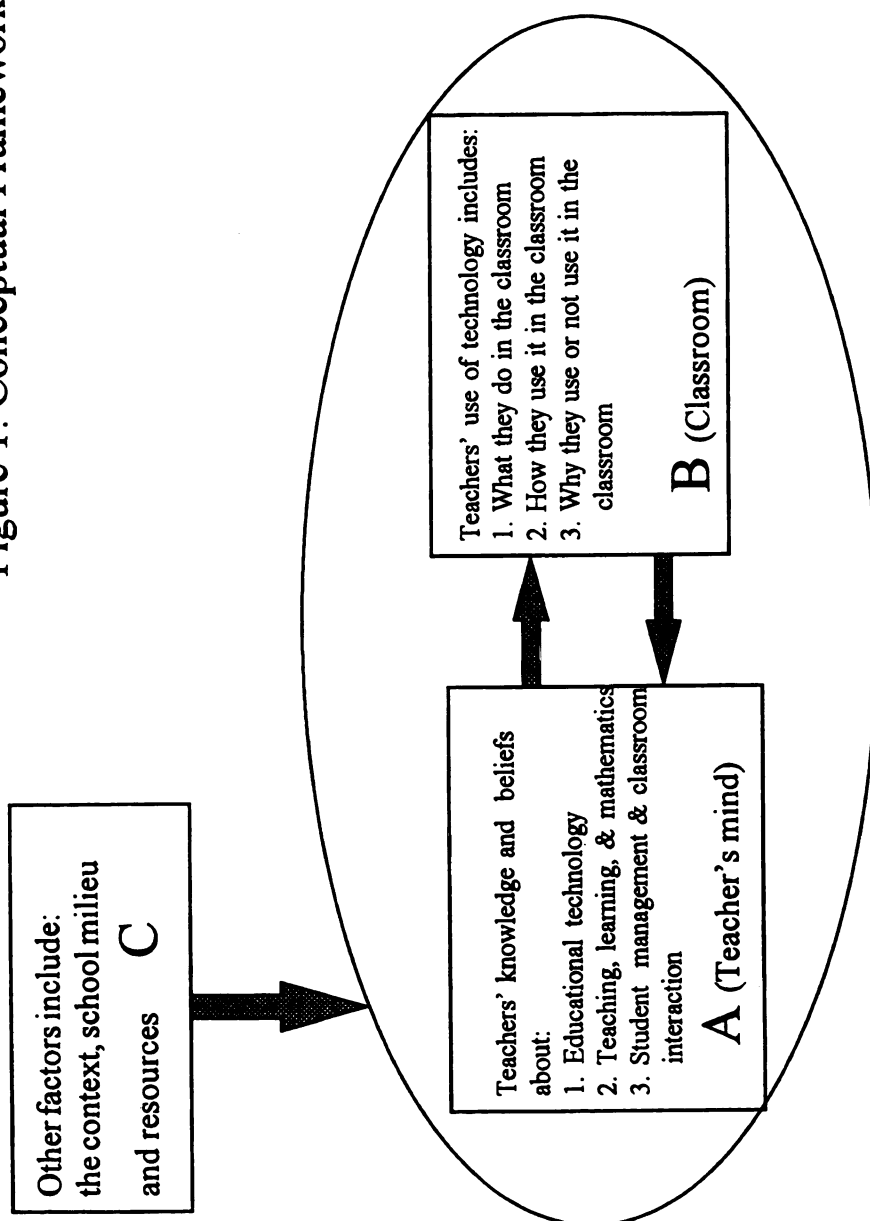
The framework is drawn from cognitive psychologists' views of how teachers' knowledge and beliefs about pedagogy and subject matter influence the way they carry out their duties (Grossman, 1990; Schwab, 1964; Shulman & Grossman, 1987). It simplifies, as do all frameworks, complex phenomena to make them understandable. One of the simplifications of the framework is the categorization of teachers' knowledge and beliefs about mathematics, teaching, learning, technology, classroom management and students' interaction. Any

such categorization of thinking is a simplification, although a necessary one for analytic purposes. Another simplification of the framework is that the framework does not address the interactions/relationships between how teachers use technology in the classroom and other complex factors that confront teachers.

The framework covers two domains: (a) the mind of the teacher, labeled A, and (b) the classroom discourse, labeled B, while recognizing the importance of a third domain -- external factors represented by C. The external factors include the structure such as the community, the district, and the school system; the school milieu, and resources. The intent of the research is to provide a better understanding of why high school mathematics teachers are not using computers and other related technologies for mathematics instruction despite the capabilities and flexibilities of these educational technologies. In other words, the framework is a tool that allows me to craft an investigation of how teachers' knowledge and beliefs influence what they do in the classroom. Of interest in this inquiry about the teacher's thinking is his/her knowledge and beliefs about mathematics, teaching, learning, technology, classroom management, and students' interaction; and the classroom discourse consists of "what" they do with the technology and "how" they use it. The study only recognizes the influence of external factors as teachers perceive them, and did not investigate them any further.

The framework rests on the following assumptions: First, teachers' knowledge and beliefs influence teachers' actions in the classroom; secondly, the teacher is central to any educational change process; and

Figure 1: Conceptual Framework



lastly, the conceptual framework is a simple model because all knowledge is intertwined and highly interrelated. The categories of teachers' knowledge within a particular system are not discrete entities, and the boundaries among them are necessarily blurred (Marks, 1990). The categorization of teachers' knowledge and beliefs suggested by this conceptual framework is arbitrary -- only designed as an analytical tool for investigation. Also, there is no agreed-upon distinction between knowledge and beliefs (Fenstermacher, as cited by Borko & Putnam, in press).

The framework focuses on how teachers' pedagogical knowledge and beliefs (about teaching and learning of mathematics) interact with their use of computers in the mathematics classroom. The rationale for this focus on teachers' knowledge and beliefs is described in some detail below.

Need for Teachers' Knowledge and Beliefs as a Conceptual Framework

What teachers know and believe guide how they construct and teach lessons, interpret textbooks, and interact with students in the classroom. (Putnam et al., 1992, p.213)

The single factor which seems to have the greatest power to carry forward our understanding of the teachers' role is the phenomenon of teachers' knowledge. (Elbaz, 1983, p.45)

My conceptual framework presumes that there is a recursive relationship between teachers' general pedagogical knowledge and beliefs about educational technology and how this technology is used for mathematics instruction as illustrated on Figure 1 above. Although studies have focused on teachers' perceptions about mathematics and on the use of technology such as

mathematics software for a specific mathematics instruction, none of the studies has focused simultaneously on teachers' perceptions about mathematics on the one hand, and, the teachers' knowledge and beliefs about using this technology for mathematics instruction on the other.

The present investigation explores simultaneously teachers' perception about mathematics and the use of technology for mathematics instruction. In order to explore this complex process, the framework draws on research that rests on the assumption that what teachers do in the classroom is fundamentally influenced by their personal views and beliefs (Thompson, 1992). The relationships between what teachers' know and what they do is not only recursive, but ultimately shapes how teachers use this tool for instruction. For example, what the teacher knows and believes may determine whether and how the teacher uses the computer in the first place, whereas, his or her experience in using the computer may change his or her knowledge and beliefs.

Several researchers have made significant contributions to our understanding of the important role of teachers and the effect of teachers' beliefs in educational practices (Hawkrige, 1990; Sheingold et al., 1981; Wedman, 1988; Woodrow, 1991a). And many have argued that the teacher is central to any educational change process (Cohen, 1988a; Brophy, 1988; McDonald, 1988). Therefore, there is a potential danger inherent in this change process, if the education reform fails to achieve change in teachers' attitude and behavior. Failure to achieve change in teachers' attitude and behavior, may constitute important barriers to successful implementation of innovation in education. In support of this claim, Schmidt and Kennedy (1990) claimed that, if reformers want to improve the content and pedagogy of teaching, they need to confront teachers'

prior beliefs first. And teachers' prior beliefs have been strongly supported by studies that suggest the resources teachers bring to teaching -- their knowledge, skills, and beliefs -- affect their actions in a number of ways, especially in teaching and learning (Putnam et al., 1992).

Providing new curriculum, new incentives or new regulation is not likely to significantly alter teaching practices if teachers either do not understand or do not agree with the goals and strategies implicit in the devices. To engage students in any useful and enriching mathematical activities involves making decisions about which textbook pages to assign, what type of software to use, and what the classroom should look like. These decisions are part of teachers' responsibilities, and such decisions may become more complex and no easier for them to make. Struggling with a new tool they have little knowledge about, and using such a new tool in creating a new learning environment has not been easy for teachers. Unfortunately, teachers are always faced with such a dilemma of changing their teaching style, especially since it is part of their job to initiate such new ideas (Clark & Peterson, 1986; Lampert, 1985).

Thus, to understand teacher's instructional practice with computers in the classroom it becomes necessary to examine teachers' prior knowledge and beliefs and the resources they bring into the classroom. This is important because what teachers already know (whether knowledge or beliefs), can influence their subsequent actions and performances in the classroom (Prawat et al., 1992). The decisions teachers make are likely based on judgment calls that reflect their knowledge and beliefs, which provide important sites for examining what teachers know and believe about mathematics and educational technology (Putnam et al. 1992).

In constructing the framework, I recognized several factors that influence teachers and the decisions they make in the classroom as shown in Figure 1. The framework also agrees that researchers may differ in defining the various components that influence teachers decision, but for the purpose of the study, these components have been categorized into three major areas: (a) the context -- the school system, district, and community; (b) the school milieu -- availability of technology, student population, and curriculum goals/objectives; (c) Resources -- funding, training, reward system, technical/expert assistance, etc. It is important to re-emphasize that the components categorized above are complex, intertwined and inseparable in any natural environment, but were used as basis for descriptive analysis.

Research Questions

This research project was based on individual in-depth interviews with experienced practicing teachers who have demonstrated involvement in mathematics reform in some ways. The focal question for this study will be the following.

1. In what ways and to what extent do teachers' knowledge and beliefs about computers, and about teaching and learning mathematics influence the adoption of computers for instruction -- the relationship between A and B as shown in Figure 1?

In order to address the focal question, I will have to explore teachers' knowledge and beliefs. Thus, three supporting questions are the following.

- 1A. What do teachers know and believe about teaching and learning mathematics?

1B. What do teachers know and believe about using computers and related technologies in teaching and learning mathematics?

1C How do teachers use computers to teach mathematics?

Finally, because factors other than teachers' knowledge and beliefs may affect their use of computers, a second question is the following.

2. What other factors do teachers perceive as affecting the adoption of computers and related technologies for mathematics instruction?

Assumptions & Clarification

The following are basic assumptions made to construct a conceptual framework which explores teachers' knowledge and beliefs about the adoption of technology in the classroom.

- 1) Computers and software are available and accessible to both mathematics teachers and students.
- 2) Teaching and learning are complex and inseparable.
- 3) The conceptual framework was structured in an attempt to categorize the issues involved in teaching and learning process, with the understanding that these structural levels do not exist, but intertwined in real life situation.
- 4) The word educational technology, technology, or computer is used interchangeably. Throughout the study, educational technology, technology or computer means computer and its related technologies, such as microcomputer, laptop, notebook, interactive video discs, CD-ROM and LCD panel.

Overview of this Document

Chapter One introduced the research problem, the purpose of the study, the conceptual framework, and a brief discussion on the need for teachers' knowledge and beliefs. This was followed by research questions, assumptions and clarifications of the study, and the importance of computer technology for mathematics instruction.

Chapter Two presents a review of research literature relevant to this study. The literature review explores teachers' knowledge and beliefs about mathematics, about teaching and learning of mathematics, about the role of educational computer as a tool for instruction in mathematics (including their hopes and fears), and about classroom management and student interaction.

Chapter Three discusses the design, methods and the rationale used for the collection of data, including the general background of the participants and why they were selected for this study.

Chapter Four presents the data collected through interviews, classroom observations, and informal discussions. Data on teachers' knowledge and beliefs are organized around key themes important for thinking about computers and mathematics.

Chapter Five discusses and analyzes meanings inferred from Chapter Four. This chapter discusses in detail the research questions, specific findings and general lessons learned from the entire study.

Finally, Chapter Six is the summary and conclusion of the study. It highlights the implications of this study both for research and for practice. The chapter raises questions for future investigation and follow-up.

CHAPTER TWO

REVIEW OF RELEVANT LITERATURE

Overview

This chapter presents the review of literature in the following areas: 1) the role of computers in mathematics instruction; 2) teachers' knowledge and beliefs about: educational technology; mathematics ; teaching of mathematics ; learning and learners; classroom management and student interaction; and 3) summary of the chapter.

The Role of Computers in Mathematics Instruction

Numerous reasons have been offered for why computers should play a prominent role in mathematics instruction. Some argue, for example, that computers and other related technologies can provide a learning environment that would allow students to explore and create both individual and collaborative learning. Others claim that educational technology will support teaching that respects and responds to students' diverse interests and socioeconomic backgrounds. This discussion on the importance of technology for mathematics instruction will focus on broad categories suggested by Hawkrige (1990).

Hawkrige (1990) used four broad rationales to summarize some of the important reasons that emphasize the use of computer for instruction: social, vocational, pedagogical, and catalytic. For convenience and relevance to this study, the vocational has been subsumed under social, and the catalytic has been subsumed under pedagogical.

Social Rationale: Children Should Be Prepared to Face the Challenges of the Information Age

Hawkrige (1990) joined the efforts of early works of Naisbett (1982), and Cetron (1985) to predict that people who lack the competence to use and understand computer technology may find themselves at or near the bottom of the national economic, social and political ladder in the *information age* society. Clearly, life in our society increasingly revolves around computer technology. Society has profoundly been altered by this technological change, and its importance is felt in all facets of the society. The proliferation and demand seem to be on a steady increase.

In the workplace, those who use mathematics for their jobs -- accountants, engineers, scientists to mention a few -- rarely use paper-and-pencil any more in their daily routines, certainly not for complex analyses. Electronic spreadsheets, numerical analysis packages, symbolic computer systems, and sophisticated computer graphics have become the power tools of mathematics in the industry. Nickerson (1988) predicted that in the future, there will be the "availability of computer networks that provide repositories of information of nearly every conceivable type, and microprocessor-based computing power will be everywhere, even in homes". The proliferation of computer-based information services for a variety of purposes, such as job

posting, want ads, and selective news, will even make it difficult for the computer illiterate to compete successfully in the job market.

Becoming comfortable and knowledgeable about computer technology has become essential for successful functioning in our society. Schools must expose students to these new technologies or risk leaving them woefully under prepared. These rationales are clear indications that the social climate now and for the future calls for a change of our current system of education. Therefore, the educational system should start creating learning environments that foster the development of each student's mathematical power through the integration of technology as recommended by education reformers, notably the NCTM (1989, 1991), and NRC (1989, 1991).

Pedagogical Rationale: Computers Improve the Instructional Processes and Learning Outcomes

Other reformers argue that computer technologies can provide important tools for improving and reshaping instruction. In the past, only high track and privileged students were viewed as active learners, and instruction geared toward understanding content and thinking mathematically was typically reserved for these select few (Resnick, 1987). Today, these goals and approaches are urged as priorities for every student (NRC, 1989; Resnick, 1987). Educators and policy makers nationwide recognize the critical need for all students to learn how to think, to understand concepts and ideas, to apply what they learn, and to be able to pose questions and solve problems.

Textbooks and curriculum materials however, "focus largely on the mastery of discrete, low level skills and isolated facts, and deny the opportunities for students to master subject-matter in depth, learn more complex problem solving skills, or apply the skills they do learn" (National Governors'

Association, 1990). Recent reforms have called for “injections” of new kinds of curricula, teaching methods and learning environments in order to accomplish the “ambitious” educational goals (Cuban, 1990; NCTM, 1991; NRC, 1989).

Effective learning from the constructivist view hinges on the active engagement of students in constructing their own knowledge and understanding (von Glasersfeld, 1991). Such learning is not a passive process; it occurs through interaction with and support from the world of people and objects through the use of technologies of many kinds (Sheingold, 1991). In this model of learning, teaching involves less telling and more supporting, facilitating, and coaching of students. Teaching becomes adventurous (Cohen, 1988a) and learning itself becomes not the acquisition of a stable body of facts and truths, but rather a dynamic process of understanding knowledge (Sheingold).

In the past, technologies have been regarded as “the answer” for solving the problems of education (Cuban, 1986), but today, these views are tempered by an understanding that it is not the features of the technology alone, but rather how these tools are used in teaching that influences learning and learners. Recently, for example, emphasis has shifted from making comparisons between instruction with and without the technology, or asking obvious questions such as, “can we teach subject X with technology Y?” (see Rockman, 1992, p.31). Rather, we have started to respond to the calls of the educational reformers, because “we now see and study technology as something that is intended to extend instruction or augment the capabilities of the teachers and students” .

The Office of Technology Assessment (OTA, 1991) recommended that:

. . . under the right conditions, new interactive technologies contribute to improvements in learning -- from helping to building basic skills through drills offering self-paced practice; to directing student discovery through simulations in science, mathematics , and social studies; to encouraging cooperative learning as students work together on computer projects in the classroom or on electronic networks across the continent.

All these findings and observations tend to suggest that the introduction of computers in schools, and their adoption for instructional purposes could improve the day-to-day operations of the classrooms (Latour, 1986).

It is true that one may argue that no one is sure how best to teach mathematics with computers, nevertheless, the NRC (1989) argued that, despite the risks of venturing into unfamiliar territory, society has much to gain from the increasing role of calculators and computers in mathematics education. For example, school mathematics should become more relevant to the students, the workplace and scientific applications. By using machines to expedite calculations, students can experience mathematics as a tentative exploratory discipline in which risks and failures yield clues to success.

However, there is a general concern expressed by teachers about students' weak mathematics background -- their inability to participate in higher-order mathematical thinking process. But weakness in algebraic skills need no longer prevent students from understanding ideas in more advanced mathematics . "Just as computerized spelling checkers permit writers to express ideas without the psychological block of terrible spelling, so will the new calculators enable motivated students who are weak in algebra persevere in calculus or statistics" (NRC, 1989). Computers and calculators in the classroom (if well used) can help higher mathematics become more accessible to every student.

In most mathematics classes, the sequence of activities is the same -- answers of the previous assignment are given back (or dictated) to students, the difficult problems are worked out by the teacher (or any willing student) on the chalkboard, and new material is assigned for the next day. These assignments are copied from pages of the textbook, and the cycle is repeated. Teachers have always claimed that this is the way they were taught, but certainly not the way they were taught to teach. Studies have documented that mathematics learning can become more active and dynamic than the traditional and dominant method, hence more effective (Lampert & Ball, 1990; NRC, 1989; Putnam et al., 1992; Thompson, 1990). By taking much of the computational burden of mathematics homework away from students, computers and calculators can enable students to explore a wider variety of examples; witness the dynamic nature of mathematical processes; engage realistic applications using typical (not oversimplified) data; and focus on important mathematical concepts rather than routine calculations (Welch & Helfacre, 1978).

Educational technology can create a learning environment that enables and encourages students to explore mathematics on their own and at their pace and ask countless "why" and "what if" questions. Although the technology will not necessarily cause students to think for themselves, they can provide an environment in which student generated mathematical ideas can thrive.

Teachers' time is precious given the type of curriculum and students they have to deal with. Some teachers regard the use of technology as an added responsibility. But, research has shown that the time invested in creating an innovative instruction based on new symbiosis of machine calculation and human thinking will shift the balance of learning toward understanding, insight, and mathematical intuition (Sheingold, 1991). The overall turn-around will yield

more gains in terms of learning, and create a dynamic and exciting experience for the teacher.

Some researchers have examined the impact of computers on learning in classrooms. For example, Ganguli (1990) compared the effect of microcomputers on mathematics instruction and found that the use of microcomputer has a significant and positive effect on mathematics achievement. Students who used microcomputer achieved a better result because they had a deeper understanding of the mathematical concepts, and were able to construct better solution strategies. Clement (1981) and Kozma and Johnson (1991) observed that there is an affective reaction of students towards the presence of microcomputers in the teaching-learning process. They suggested that increased understanding of how computers affect learning and teaching may even bring about revolution in higher education. Therefore, it is necessary to examine computer capabilities very closely, because it might be a critical factor to explore in transforming the classroom.

O'Connor (1992) observed that the teaching-learning process has not improved with the use of technology because teaching style and classroom environment have not changed. This suggests that teachers are still working in unfamiliar territory --using the "new wine" in an "old cup". For instance, teachers use computer and overhead projector as substitutes for textbook and chalkboard or paper-and-pencil. Although the physical arrangement of students may change, however, the instructional practice in the classroom still consist of the teachers' existing ways of thinking about learners (Schreiter & Ammon, 1989). Nonetheless, studies have shown that schools that use computers for classroom instruction are making remarkable progress towards meeting the demands of the "envisioned classroom" of the 21st century (Ganguli, 1992).

In conclusion, educational technology is favored as one of the important vehicles to drive desired change in schools. Thornburg (1992) stated, 'unless education adopts and adapts to new technologies, our schools will soon lose their relevance as primary places of learning' (p.3). The assertion that technology is likely the catalytic change agent in education rests on the power and flexibility of the tool. Nickerson (1988) described some of the capabilities and potentials computer technologies hold for the future.

14. The speed of the devices used for computing and for storing will continue to increase, while their size, power requirements and cost will continue to decrease.
15. Availability of extensive software applications that are relevant to education.
16. Availability of software that will permit the supplementation of conventional text with dynamic graphics, including process simulations, that should enhance the effectiveness of expository material.
17. Availability of multimedia communication facilities, that allows the mixing of the text, images, and speech.
18. Availability of user-oriented languages and "front-ends" application software.

However, the troubling issue is, even though the merits of technology have been observed more than ten years ago, there is little indication that the situation is different. While very few schools and teachers are making desired efforts toward integrating technology into the classroom discourse, most others are yet to begin. Teachers of the "old school" are still resistant to change because they have not seen convincing justifications for using technology for instruction. These teachers of "old school" claim that the few teachers who use educational technology in their classroom have not transformed students to construct their own mathematical knowledge, or to explore the higher-order mathematical process. Research also suggests that if teachers are not

convinced about the usefulness of an innovation they are unlikely to make significant changes in their practice (O'Connor, 1992; Sheingold & Hadley, 1990). When teachers set out to adopt a new curriculum or instructional technique, they learn about and use the innovation through the lenses of their existing knowledge, beliefs, and practices (Cohen & Ball, 1990; Putnam et al., 1992). To a large extent they are still struggling with their existing mind set.

Since it has been recognized that it is extremely difficult to mention all the factors (external & internal) that influence teachers' actions in the classroom, this study is only focusing on teachers' perceptions about the use of technology for mathematics instruction. Due to the importance of teachers' general pedagogical knowledge and pedagogical content knowledge and beliefs about the use of educational technology in mathematics subject domain, further literature review will focus on teachers' knowledge and beliefs about mathematics, learning and teaching, the role of technology in mathematics instruction, and classroom management and student interaction.

The remainder of this chapter reviews literature that is related to teachers' knowledge and beliefs about 1) educational technology, 2) teaching, learning and mathematics, 3) classroom management and students interactions.

Teacher' Knowledge and Beliefs

In proposing a research paradigm for studying teachers' knowledge and beliefs about the use of technology, relevant literature on teachers' knowledge and beliefs in education was reviewed. Cognitive psychologists have been able to categorize various types of knowledge and how they influence teachers in the way they do their jobs (Grossman, 1990). This study focuses on "General

Pedagogical Knowledge” and “Pedagogical Content Knowledge”. Cognitive psychologists define general pedagogical knowledge.

General pedagogical knowledge includes a body of general knowledge, beliefs, and skills related to teaching: knowledge and beliefs concerning learning and learners; knowledge of principles of instruction,....., knowledge and skills related to classroom management (Doyle, 1986); and knowledge and beliefs about the aims and purposes of education (Grossman, 1990)

Pedagogical content knowledge is the following.

The most useful forms of representations of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations -- in a word, ways of representing and formulating the subject that makes it comprehensible to others. Pedagogical knowledge also includes an understanding of what makes the learning of specific topic easy or difficult; the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons (Shulman, 1986a).

The literature review will focus on teachers' knowledge and beliefs with the above concept of knowledge in mind. This includes knowledge of various strategies and arrangements for effective classroom management; instructional strategies for conducting lessons and creating learning environment

Studies that focused on teachers' general pedagogical knowledge and beliefs, and subject matter knowledge in teaching and learning of mathematics have demonstrated its importance for effective classroom discourse (see Ball, 1988a; Heaton, 1992; Grossman, 1990; Putnam, 1992; Prawat, 1992; Shulman, 1986a). Other studies that also investigated the role of technology as an instructional tool, have shown proofs that technology among other things provides a creative learning environment that stimulates active learning. (see Ganguli, 1990; Hawkridge, 1990; Kulik, Bangert, & Williams, 1983; Rockman, 1992; Sheingold & Hadley, 1990). In reviewing all these pieces of important information, It was discovered that little has been done on teachers' knowledge and beliefs with specific emphasis on the use of technology for mathematics instruction.

Since the traditional method of teaching has continued to disenchant students, there is an increasing pressure on teachers to try new innovative ways of delivering instruction to students. One of the prescribed ways of creating a new learning environment that may alter the traditional method of teaching involves the use of educational technology as a tool for mathematics instruction. Studies have shown that technology can be a powerful and flexible tool for instruction; sadly, its presence is hardly seen in most classrooms. The literature has revealed that much has been done in the field of research, but more has to be done in order to understand why mathematics teachers are not using this tool most often in the classroom. These unobservable conceived teachers' perceptions provide the platform for this inquiry.

Teachers' Knowledge and Beliefs about Educational Technology

The prime movers in educational reform are teachers, who are increasingly being viewed as important agents of change (McDonald, 1988). Teachers are at the center of any school-based innovation, and what they learn to do with technologies will define the impact of technologies in their classrooms (Sheingold, 1992). To the extent that 'teacher education has not begun to address the integration of technologies in schools (almost without exception)' much of what teachers learn they learn on the job (Ball, 1990b).

There is scant research on teachers' knowledge about the use of computer technologies for instruction and no mature, well-studied examples of technology integration in schools and teacher education, but there are general surveys on teachers' knowledge, beliefs and attitude/behavior about computers (International Studies in Educational Achievement (IEA), 1991; Sheingold & Hadley, 1990). Studies have documented that teachers' knowledge and beliefs

about what they use for practice impact how they actually use it during practice (Clark & Peterson, 1986). Therefore, in order to create a learning environment that promotes "meaningful" learning, teachers' knowledge and beliefs of and about the use of computer technologies for instruction is important. This is evident in the IEA survey that indicated teachers' lack of knowledge, lack of interest, lack of training, and inexperience with computers accounted for more than 50% of why computers have not been integrated into education.

Some argue that teachers have lost the initiative and leadership regarding the use of technology in instruction. Callister and Dunne (1992) argue that technology enthusiasts have exaggerated the capabilities of the tool, and policy makers seem to be forcing computers on teachers without preparing teachers well enough to handle the tool. This trend has left most teachers to perceive the machine as a "master" and not as a servant. Ultimately, teachers who hold this negative view about the role of computers have carefully avoided using it for instruction and lost interest in anything computing. According to Woodrow (1991), "if teachers perceive a new technology negatively, the success of that technology will be limited", and will resist all attempts that will make the technology successful (see Choo & Cheung, 1990; Muller, Husband, Christon & Sun, 1991).

According to Sheingold, (1991), the amount of computer experience has an effect on attitude toward computers. Teachers who have quite an extensive knowledge about computers have positive attitudes toward computers. Conversely, teachers with little or poor knowledge about computers have negative attitudes. In a large sample of teachers surveyed by Pelgrum, Reinen, and Plomp (1993), most of the teachers felt it was important for teachers to have

knowledge of computers in order to use them in instruction, with more than 50% of the teachers rating this knowledge "very important".

Prior beliefs in a variety of contexts can also influence how new information is interpreted (O'Laughlin & Campbell, 1988). For example, teachers tend to follow the footsteps of their own teachers (Ball & McDiarmid, 1990), who incidentally never used computer technologies for instruction. Even at the college level, attempts to infuse technology into the traditional methods and courses remain a difficult task due to faculty/teacher reluctance and inexperience with computers (Aworuwa, 1994). There are several reasons documented by other research findings why technology has not been used in the classroom. These reasons have been summarized as barriers to why teachers are not using computer for instruction:

19. Most teachers currently in the system were not raised in the electronic era. Little or no pre-service preparation for teachers includes: 'no systematic in-depth experience with technology that articulates what those teachers could expect as little as five years into their professional lives; and Schools of Education mirror the schools themselves as technological ghettos and thus help perpetuate the status quo' (Kaput, 1992).
20. Many teachers have strong negative affect toward computers owing to their knowledge about mathematics and science which also arouse negative affect (OTA, 1988).
21. Practicing teachers should be expert practitioners, but training and the type of training is inadequate and most of computer teachers are not well trained (Sheingold, 1992; Barker, 1991).
22. Some teachers have expressed fear about the consequence of unavailability of hardware and software, in addition to high cost of educational computing, teachers are concerned about obtaining resources for sustained computer-based innovations in the classroom for the future (Kozma & Johnson, 1991). On the whole few resources have been spent on technology for teachers personal productivity and teaching (Hasselbring, 1991).

These barriers reflect the consequences of teachers' lack of or poor knowledge about educational technology and beliefs about its role as educational tools for classroom instruction. Research studies support that little or no understanding of the technology contributes to teachers' reluctance and resistance. From a recent survey of "Accomplished Teachers" conducted by Sheingold and Hadley (1990) revealed that most teachers who are now comfortable with the use of computer as a tool for instruction have some knowledge about the use of machine. However, the study noted that these teachers who achieved reasonable level of comfort devoted their own time learning how to use it, and have continued to spend some time trying to use computers for instruction. In summarizing their study, Sheingold and Hadley concluded that teachers' knowledge and belief about educational technology is necessary for any meaningful professional use of the tool in the classroom.

For teachers to teach in a new way that will facilitate active construction of knowledge by students -- described in detail by Schoenfeld (1988), they must make a change in their professional style, and it demands a change in their attitude. This change in attitude is necessary because it is difficult for a teacher to admit the potentials of a tool that he or she lacks expertise. In addition, teachers have a long tradition of being "experts" and have been associated with authority, the fear of not being experts may even lessen the teachers' authority, and therefore, instill fear of embarrassing themselves in front of the students.

Teachers' knowledge and beliefs about the role of technology in mathematics are critical in this transformation process, because, after the transformation it requires knowledge and interest to sustain the change. In the past, many educational innovations have failed to be effective because, they were not adopted into traditional teaching styles (Watt, 1984), and history

suggests that the teachers' role is important, because enthusiasm and "hype" alone are insufficient to sustain a medium of instruction. It requires a careful and systematic approach that captures the interest of teachers who are eventually the ultimate users.

Studies in the past placed emphasis on making comparisons between instruction with and without the technology without investigating the thoughts and beliefs of the teachers who ultimately are the users of the technology. Today, we are beginning to see and study technology as something that is intended to extend instruction or augment the capabilities of the teachers and students (Rockman, 1992). Hence, teachers' perspectives, like our technologies, should begin to change from the traditional style of teaching to student-centered-type of instruction (Kozma, 1991). Integrating technology into teaching practice from teachers' perspectives no doubt is a complex professional development process which is beyond the scope of this study (for detailed review of changes in teachers' knowledge and beliefs see Borko & Putnam, in press). This, however, raises the question of what type of decisions should teachers make about the use of technology for instruction in the classroom? How would such decisions which depend on teachers' prior knowledge and beliefs reflect the intent of mathematics reformers?

These professional challenges increasingly demand further inquiry into teachers' knowledge and beliefs about the role of educational technology in teaching and learning of mathematics. Sheingold (1992), has called for an educational framework that connects technology with visions and goals for "what and how" students learn, "what and how" teachers teach, and the kinds of learning and teaching environments schools should become. Since technology is still in the nascent stage, teachers are faced with the rigors of experimenting

alternative ways of using computers with students; learning new ways of teaching by observing students using computer technology; and noticing, being challenged by, and taking advantage of the new forms of classroom organization and management afforded by the technology. All these developments provide opportunities for teachers to re-assess what they know and believe about technology, in order to consider and reshape their classroom practices and pedagogy.

Viewing the computer itself as a learning tool has strengths and weaknesses. Its speed, storage capacity and flexibility are some of its advantages; however, what is important is how teachers should be using and thinking about computers? For example, it is a common experience that if instruction is unguided, students may not know how to explore and draw conclusions. The design of instructions and selection of appropriate software demands the skill and knowledge of the teacher. Teaching in an era of computerized instruction requires teachers to demonstrate a high level of proficiency in using computers (Novak & Knowles, 1991). Teachers' proficiency in using computers should be sustained by teachers' knowledge and beliefs. Boyer (1984) recommended that "schools should relate computer resources to their educational objectives. Furthermore, all students should learn about computers, learn with them, and, as an ultimate goal, learn from them". Achieving this goal requires teachers' perseverance and personal conviction.

It seems apparent that some strands of research studies that support the computer as an instructional tool base their rationale on its flexibility and efficiency (efficiency here means having more computational skills and faster ability of retrieving information). Another school of thought holds that the capability of computer alone should not be the basis of computer integration in

classroom. Rather, teachers' understanding of this piece of technology and its usage is more critical (see Sheingold et al., 1981). Although the flexibility and efficiency of the computer are useful and critical, such powerful characteristics are not significant if teachers are not familiar with the equipment in the first place. Hence, Sheingold et al. expressed their concern when they argued, "while efficiency is an argument often used in support of computing in education, the goal of efficiency may be detrimental to teacher morale and productivity". Research suggests that teachers should be educated well enough about the use of computer and computer technologies before they can apply it (Buddin, 1991; Bychowski & Dusseldorp, 1984), and short workshops are not enough to adequately empower teachers.

In summary, confronting teachers' knowledge and beliefs about the role of technology is important because of its impact on classroom discourse. Since integrating technology into teaching practice is as complex as the process of professional development itself, attempts to investigate deeply teachers' perceptions about mathematics, teaching, learning, and classroom management and students' interaction become critical factors in this study.

The next two sections will review relevant literature about teachers' knowledge and beliefs about mathematics, teaching, learning, and classroom management and students' interaction.

Teachers' Knowledge and Beliefs about Mathematics, Teaching, and Learning

Teachers have been referred to as dilemma managers because of the nature of their profession (Berlak & Berlak, 1981; Lampert, 1985), especially what they do in the classroom. Teachers are always faced with challenges due to the nature of the classroom such as diverse groups, different mathematics

abilities, and disciplinary problems. The way teachers negotiate a balance when confronted with such classroom dilemmas draws heavily on their knowledge and beliefs about the subject-matter (mathematics), teaching and student learning. Because teachers' knowledge and beliefs influence both their actions in the classroom and their interactions with students, this section will focus on research that informs us about what teachers know and believe about mathematics, teaching, and learning. In addition, Becker (1985) suggested that teachers' attitudes toward computers do not relate to sex, age, or job, but relate more to their perception of mathematics, and this implicitly influences their teaching style.

Teachers' knowledge and beliefs about mathematics.

Without knowledge of the structures of a discipline, teachers may misrepresent both the content and the nature of the discipline itself. Teachers' knowledge of the content to be taught also influences what and how they teach (Shulman & Grossman, 1987)

Knowledge of mathematics is obviously fundamental to being able to help someone else learn it (Ball, 1988a, p.12)

Teachers' comfort with, and confidence in, their own knowledge of mathematics affects both what they teach and how they teach. Teachers' conceptions of mathematics shape their choice of worthwhile mathematical tasks, the kinds of learning environments they create, and the discourse in their classrooms. Thompson (1984) argued that teachers' mathematical knowledge on the instruction they provide have considerable effect on learners, and Ball (1990b), noted that teachers' poor mathematical knowledge is filled with "sparse webs" of knowledge that make few connections among important mathematical ideas.

There is a growing body of knowledge that supports that teachers' subject-matter knowledge impacts the content and type of instruction that occurs in the classroom (Ball, 1990; Brophy, 1991; Even, 1993; Grossman, 1990; Putnam et al., 1992; Schoenfeld & Arcavi 1988; Shulman, 1986). For example, a Stanford project led by Shulman (1986, 1988; Wilson, Shulman, & Richert, 1987) showed that teachers with greater mathematical knowledge were more conceptual in their teaching, whereas teachers with lower levels of knowledge were more rule based.

Schoenfeld (1988) argued that while teachers who view mathematics as conceptual and consisting of connected ideas tend to engage students in mathematical behavior in circumstances where such behavior is appropriate. Other teachers who consider mathematics solely as a discipline that provides prepackaged solutions for prepackaged and formally stated problems may not use it when appropriate. The latter is present in almost all mathematics classrooms. But studies have documented that if knowledge is procedural and sparsely connected, it is likely to be associated with a belief that the study of mathematics is the acquisition of computational procedures. It is also likely that teachers who hold this narrow view lack not only certain understanding, but also a vision of the kind of understanding that is possible and appropriate in mathematics (Simon, 1993).

Unfortunately, many teachers hold such narrow views of mathematics. Studies have shown that teachers believe that the computational algorithms that pervade the traditional curriculum constitute the core of mathematics (NCTM, 1989, 1991; NRC, 1989). Thompson (1984) found there is consistency between teachers' professed conceptions of mathematics and the manner in which they typically presented the content. Of the teachers studied by

Thompson, one who held a narrow view of mathematics rarely spoke of practical applications of mathematics, whereas, another teacher who viewed mathematics as a subject that provides opportunity for high-level mental work explained to the students the importance of these processes in the acquisition of mathematical knowledge. Although the teachers Thompson studied hold beliefs that differ in important ways from the visions of mathematics reformers, these beliefs are consistent with the ways in which they themselves were taught (Ball, 1988), and with views of mathematics held by much of the general public (Ball, 1988; NRC, 1989; Paulos, 1988; Putnam et al., 1992).

Teachers who hold narrow views about mathematics generally feel it is their responsibility to direct and control all classroom activities. They tend to present the lessons in an orderly and logical sequence, avoiding the kinds of digressions needed to discuss students' difficulties and ideas. In contrast, teachers who view mathematics as a connection of ideas, forms, and shapes tend to create and maintain an open and informal classroom atmosphere. Often, a lack of a deep understanding of mathematics can lead to some anxiety or attitude toward mathematics that are negative (NCTM, 1989).

Hashweh (1986) whose research focused on science, found that teachers who had more subject-matter knowledge were more likely to notice misleading or poorly articulated themes or explanation in texts. Those teachers were also likely to reject a textbook's organization of materials when it did not match their own understanding. Hashweh stated, "teachers with a richer understanding of the content were more likely to detect students' misconceptions, to utilize opportunities to 'digress' into discipline-related avenues, to deal effectively with general class difficulties and to correctly interpret students' insightful comments' (p.305). The results of these studies

support our daily experiences both in workplace and the classroom. If you barely know something, you feel threatened when confronted with a question, especially when the question requires an extension of an idea, such as "why" and "how". Teachers are human and are constantly faced with such questions from inquiring intellect of students. Conversely, a teacher may be unable to pick up a student's suggestion that represent a different but equally valid way of thinking about a mathematical concept or solving a problem. Thus a lack of deep understanding of mathematics may lead to lessons that are teacher directed and school mathematics that is packaged and sterile --unpleasant, rigid, and unstimulating (Ball, 1991).

As the challenges of the society continue to increase, students need more mathematics to be productive as a workforce. Secondary mathematics is quite complex and demands more knowledge of mathematics from secondary mathematics teachers. Thus, it is critical for them to alter their teaching style in ways that attend to the demands of the students. For instance, secondary school mathematics encompasses mathematical ideas, facts, and concepts, and the relationships between and among them. When treating the mathematics in this way, teachers may be put in situations where they have to deal with unfamiliar territory which calls for a firmer grasp of the subject-matter. Teachers must also be knowledgeable with the processes of doing and creating mathematics for understanding. In order to select and construct fruitful tasks and activities for their pupils, as well as interpret and evaluate ideas flexibly, teachers must understand the mathematical concepts and procedures. For teachers to be "maximally effective" in teaching mathematical concepts (i.e. not restricted by their level of mathematical knowledge) "they must have an understanding of the concept that allows them to examine it as a cognitive object" (Simon, 1993).

Most practicing teachers believe that they know enough mathematics to teach high school mathematics effectively. However, they seem to hold different views about what the goal of mathematics instruction should be. Some regard the learning of mathematics as the acquisition of computational skills, others view it as the understanding of concepts and relationships that define the structure of mathematics, and many view it as the development of problem solving skills. Teachers' knowledge about mathematics influences their views and beliefs about the goal of mathematics which shape how they teach the subject (Ball, 1990b). Though considerable research has examined subject-matter knowledge and pedagogical content knowledge in detail, it is not still clear how much and what kind of knowledge is sufficient for teachers to have in order to teach for conceptual understanding. Some even argue no one can really teach mathematics, but rather can only stimulate students to make sense of the subject. Based on a constructive approach to learning, the teacher's main function as Noddings (1990) and Confrey (1990) stated, is to establish mathematics environments that encourage exploration and strong acts of construction, environments in which students are encouraged to explore and raise questions as advocated by mathematics reformers, notably the committee on *Professional Standards for Teaching Mathematics* (NCTM, 1991). Further studies are needed in this domain.

Most studies on teaching in the past have simply looked at what teachers do in the classroom, as opposed to investigating what they know about what they are doing therein (Clark, 1988). Predictably, the nature of problems teachers develop and/or provide for students is connected to their own views about what constitutes "good" problems for their students (Putnam et al., 1992). Teachers who view mathematics as rigid and fixed set of rules and procedures

to be mastered are likely to approach the subject as a set of procedures and steps; whereas those who see mathematics as a multiple representations of connected concepts and procedures with relationships with other school subjects tend to treat it as a creative and enjoyable discipline (see NRC, 1989; NCTM, 1991). Stein et al., (1990) reported how a fragile grasp of mathematics content led to an overemphasis on rules and procedures at the expense of what might be considered more meaningful content. In another study, Steinberg et al., (1985) explained that teachers who had the surest grasp of mathematics were best able to explain during instruction why mathematical procedures do or do not work, and how knowledgeable teachers tend to stress more important ideas and were less didactic in their instruction.

In sum, 'clearly, teachers must know mathematics well in order to teach it well' (Brown & Baird, 1993). Teachers' knowledge about mathematics influences their views and beliefs about the goal of mathematics which shape how they teach the subject (Ball, 1990).

Teachers' knowledge and beliefs about teaching mathematics.

... within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representations of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations -- in a word, ways of representing and formulating the subject that make it comprehensible to others (Shulman, 1986a, p.9-10)

Teaching is the primary task of teachers, but what and how they teach varies from one teacher to another. Teachers' knowledge and beliefs about teaching are critically important to what the student learns in the classroom. In general, the experiences that mathematics teachers have while learning mathematics themselves have a powerful influence on the education they provide to their students. Teachers tend to follow their own footsteps (Ball &

McDiarmid, 1990), unless they have developed a different repertoire of teaching skills and the knowledge and beliefs to support teaching differently. Through these experiences, they develop ideas about what it means to teach mathematics, beliefs about successful and unsuccessful classroom practices, and strategies and techniques for teaching particular topics. Even experienced teachers are highly influenced by what they already know and believe about teaching, learning, and learners. However, experienced teachers' beliefs about teaching have been influenced by their practical experience and other contextual factors such as gender, race, class size, and school culture.

Recently mathematics reformers, cognitive psychologists, and teacher educators have called on teachers to attend to the way they teach mathematics because teachers' conceptions about teaching impact how they conduct their daily activities in the classroom. These activities include how they construct their lessons, interpret textbooks, and interact with students. Since all good teaching requires sound knowledge, preparation, and effective delivery style, good teaching relies heavily on teachers' judgment, knowledge and beliefs (NCTM, 1989). Teachers also continually draw upon knowledge of strategies for conducting lessons and creating learning environments. Regardless of the instructional approaches they adopt, teachers still need to know how to arrange the classroom, organize classroom activities, think pedagogically about the subject matter, and interact with students to ensure smooth running of the task of teaching (Leinhardt & Greeno, 1986).

Understanding mathematics for teaching also means being able to understand the instructional strategies and the culture of the classroom. Teachers must view mathematics through the eyes of the students (Dewey, 1916/1964a). For example, students must be able to understand what they

learn, they must enact for themselves verbs that permeate the mathematics curriculum: examine, represent, transform, solve, apply, prove, and communicate. This happens most readily when the students work in groups, engage in discussion, make presentations, and in other ways take charge of their learning (see NCTM, 1991, Lampert, 1986b). Teachers also need to be able to appraise curricular materials and instructional activities, assess what their students understand, and plan ways to help them learn.

Researchers are increasingly arguing that for teachers to make meaningful changes in their instructional practices, they must become more reflective about their practices and must be more willing to reconsider their practices on the basis of these reflections (Schon, 1991). For example, teachers who try to use more creative ways to teach mathematics should constantly reflect on their methods, because the traditional way of teaching lurks beneath the surface. 'Knowledge and beliefs provide important lenses through which teachers perceive and act on various messages to change the way they teach' (NCTM, 1989). Studies conducted by Ames (1983) and Pratt (1985) suggested that teachers who believe that teaching is important, and that students success is generally feasible given the context, have a general value orientation that teachers are "responsible" for their students. That is, they believe that they can make a difference in student success or failure in learning. Conversely, if teachers do not believe that their teaching is what makes the difference in student success or failure -- especially if they feel it is the responsibility of the student, then they are less likely to view teaching as a valuable endeavor, and to put time and effort in it.

In sum, teachers' knowledge and beliefs about teaching are important to what students learn in the classroom. New collaborative efforts of researchers

with mathematics teachers are encouraged because it has been successful in changing teachers' views about students and learning, and has helped them to rethink their teaching (e.g. Ball & Rundquist, 1993; Wood, Cobb, & Yackel, 1990, 1991). For example, Rundquist, one of the mathematics teachers who participated in the collaborative efforts, through her experience in the mathematics project has been able to change her teaching style in other subject matter. Since teachers in professional development schools are beginning to show interests and are participating in similar collaborative efforts, there is more likelihood for teachers making more meaningful changes in their instructional practices.

Teachers' knowledge and beliefs about learning and learners. Research suggests that teachers' knowledge and beliefs about learners also influence their teaching: what they teach, in what ways, to whom, and how they think about their students' success or failure in learning mathematics (Anyon, 1981; Ball, 1988a; Brophy, 1983; Steinberg et al., 1985). In an example of these sorts of beliefs, two of the four teachers studied by Steinberg et al., (1985), believed that ability to learn mathematics was an innate human characteristic. One said that some people have natural flare for mathematics -- having "mathematical minds", and other believed that individuals are able to think in either from human-angle or scientific-angle, where thinking is more of logic and inflexible.

Other research has also indicated that the ways teachers think about learning and how to foster it interact with other factors which shape classroom instruction and the ways students make meaning out of it (Thompson, 1992). For example, teachers draw on their knowledge and beliefs to mold what is important for students to know about mathematics and by the context of

classroom instruction (Wilcox et al., 1992). While most high school teachers enjoy and feel competent in mathematics, many have different beliefs about how best to impart this knowledge to learners. Some teachers based on their beliefs organize their instruction to meet their personal expectations, some are geared more toward attending to the needs of the students, while others plan their lessons to cover the curriculum irrespective of the knowledge base of the students and their difficulties. Even though secondary teachers seem to like mathematics, often their reasons for liking it are basically a reflection of either their beliefs about what mathematics is or of their level of understanding of the subject (Brown & Baird, 1993).

It is important to note that contextual constraints such as rigid curriculum, administrative pressures, and other demands can discourage teachers from enacting the type of instruction that is congruent with these beliefs (Wilcox et al., 1991). However, contextual factors that influence teachers' beliefs about student learning extend beyond individual classroom situations. To illustrate one of the contextual factors, there is an increasing number of the poor and minority students in public schools. The vast majority of students never move beyond the basics in mathematics because they cannot persist in subsequent work to reach the point where the 'veil of confusion is lifted' (NRC, 1989). This multi-cultural classroom is increasingly becoming a critical contextual factor that shapes teachers' beliefs about classroom discourse and learners' learning.

Teachers' views about what is important for students to learn in mathematics also influence their beliefs about what to teach and how to teach it. Teachers frustrated by students' lack of enthusiasm and prerequisite knowledge resort to drill and practice lessons on skills, rather than problem-solving oriented lessons (Brown, 1986; Cooney, 1985). Calderhead (1984)

showed that secondary school mathematics teachers' knowledge and beliefs about students and students' learning also have a major impact on how teachers interact with students in the classroom. Calderhead suggested the following.

It is important that teachers should know their students' home backgrounds, their experiences outside the school, and other ranges of knowledge, skills, and interests which enable them to plan activities, to avoid or cope in advance with many potential instructional and managerial problems (p.55).

However, there is an inherent danger in that, because teachers who believe that poor and minority students are low mathematics achievers will likely place them at the lowest levels of the schools' sorting system (Oakes, 1985, 1990).

In addition, teachers' expectations influence the expectations of students regarding the discipline of mathematics. Thus, teachers' influence has been considered to be a significant factor underlying students' experience and achievement in mathematics (Borasi, & Siegel, 1990; Schoenfeld, 1985). Given what we know about most American classrooms, students who have gone through years of rigid and rigorous computational algorithmic approaches tend to hold a strong procedural and rule oriented view of mathematics. The implication of this assumption is that, they view mathematical questions as procedures that should be quickly solvable in just a few steps, the goal being to get the right answer (NRC, 1989).

Many Teachers in high schools believe that most students have failed to be responsive in mathematics because they were poorly prepared in the lower classes to cope with the rigors of mathematics and because most students come from homes (especially the low SES) that hardly prepare them for any meaningful learning. This perception filters down to the classroom. For example, teachers who have low expectations for students who come from the

working class and low SES families create a learning environment where knowledge is told to them and is found in books. Mertz (1978) indicated that low ability students prefer seat work to lecture and classroom interactions. Teachers who sense these low ability students' preferences and entertain low expectations for students will tend to engage in behavior that maintain both the students' and their own previously formed low expectations, by assigning lots of worksheets for seat work, low-level questioning, and the like.

Recently, the current movement by researchers toward asking teachers to start attending more to the ways students think and learn about subject matter especially in mathematics , is becoming critically important, both as a goal for what needs to be changed and as a starting point for other changes in knowledge, beliefs, and practices (Borko & Putnam, in press). However, if teachers do not share the vision prescribed in NCTM *Curriculum and evaluation standards for school mathematics* or even perceive of them as minimally influential in effecting learning, it is unlikely that they will ever implement those standards. For teachers to choose to teach according to this vision, they must believe that the mathematics and approaches to teaching described in these NCTM documents are indeed valuable.

In sum, a synthesis of the research on teachers' beliefs on learning, reviewed by Thompson (1992) noted that teachers have preconceived notions about how students learn, and these preconceived ideas shape how mathematics gets taught in the classroom. Teachers' beliefs and perceptions about student learning are also connected to their views about mathematics and subject matter knowledge of mathematics (Ball & McDiarmid, 1990; Wilcox et al., 1992). Even though teachers' beliefs about students and students' learning impact instruction, Hoyles (1982) found that students on their own want

security and structure when studying mathematics -- they always want to get it right. Motivated by these views of students, it is more than likely that students' views might also influence the approaches that a mathematics teacher can successfully take in the classroom. Finally, beliefs about learning are also related to what is being learned. What teachers know and believe about mathematics necessarily influences their beliefs about how students learn it (Putnam et al., 1992).

Teachers' conceptions about classroom management and student interaction. According to Doyle (1986):

Classroom teaching has two major tasks -- promoting order and learning. The task of promoting order is primarily one of establishing and maintaining an environment in which learning can occur. To accomplish this task, teachers must have repertoires of strategies for establishing rules and procedures, organizing groups, monitoring and pacing classroom events, and reacting to behavior.

Teachers' views about students, what is important for students to learn in mathematics, and how students learn also influence their beliefs about classroom management and the type of interaction that is encouraged in the classroom. For example, teachers who believe in cooperative learning organize the learning environment to reflect that, while those who believe in didactic pedagogy arrange their classroom differently. But central to the NCTM (1991) framework is the creation of a curriculum and an environment in which teaching and learning are to occur in ways that are very different from much of the current practice. And strands of research from cognitive psychologists' investigations of classroom learning seem to produce one central lesson: Learners should create, revise and contribute to knowledge and, if possible, to the community of learners in the classroom. To recognize the constructed nature of learning and the rich opportunities that mathematics can provide to the teacher who needs to

required for the discipline must be contributed by all members of the group (Bereiter & Scardamalia, 1994 ; Brophy & Good, 1986; Hawkins & Pea, 1987; Resnick, 1987). For teachers to establish this creative learning environment (one whose discourse supports the use of technology), they must have the skills, experience and ultimately believe in that type of classroom culture. According to Carpenter et al. (1988) classroom management and organizational constraints are important reasons why so little hands-on, inquiry-based, or cooperative learning activities occur in mathematics classrooms and why there is heavy reliance on seat work and routine recitation-type activities. "When effective management routines are not in place, more complicated instructional formats -- ones that research suggests are more likely to develop communication, reasoning, inquiry, and problem-solving skills -- are almost impossible to conduct " (Goldman & Barron, 1992). Though researchers believe that computers in the hands of "expert" teachers should help stimulate a learning environment that entails the active construction of knowledge by learners based on what they already know, rather than the absorption of knowledge as presented by others (see Resnick, 1987; Shuell, 1986), not much has changed in the classroom.

Apart from the expressed concern of cognitive psychologists, the public and policy makers believe that the rapidly growing technology in the workplace may drive the adoption of technology in schools and spur collateral changes. Some reforms argue technologies in the schools make possible a shift from lecturing to coaching and from a competitive to a cooperative social classroom structure (Newman, 1992; Thornburg, 1992). Administrators on the other hand, typically think of simply providing computers to use. The administrators feel that computers are straight forward tools that will assist teachers in carrying out pre-

computers are straight forward tools that will assist teachers in carrying out pre-existing tasks and fulfilling pre-existing roles, whose acceptance requires the acquisition of an entirely new set of skills. Unfortunately, most teachers have little or no skills and experience about either organizing or managing this new learning environment, coupled with their stated anxiety of losing their control to the students (Hodas, 1993).

Teachers who are more successful integrating computers into classroom instruction are those who are proficient in their subject-matter and interested in cooperative, group learning, and individualized instruction are trying to integrate computers in classroom instruction (Sheingold & Hadley, 1990). In contrast, teachers who hold either a narrow view of the subject-matter, or lack the skills and experience of integrating technology in instruction may argue differently. Another reason is, beginning teachers who have to unlearn in order to learn this new approach against their preconceived notion of teaching-learning of mathematics may not have the time and perseverance to do so. And some convictions may be resistant to change and may even interfere with what students try to learn. If, for instance, beginning teachers preconceive computer-use as a remedial tool -- and find them threatening besides -- may find it extremely difficult to move beyond the exclusive focus on drill and practice.

A consistent finding across many sites and studies is that technology-infused classrooms are organized in a more student-centered fashion (Collins, 1991; Cumming, 1988; Gearhart, Herman, Baker, Novak, and Whittaker, 1991; Herman et al., 1991; Mandinach, 1989; Sheingold and Hadley, 1990). In the traditional classroom setting, the teacher plays an important role in facilitating transfer of knowledge through telling. With the teacher often so removed from the computer activities, he/she does not have the information necessary to

support such transfer (O'Connor, 1992). Therefore, teachers' responsibilities to students will change, and this type of change may be contrary to the beliefs they hold. Teachers' fear may have been heightened because some studies have also shown negative effect of improper use of computer for instruction on students. Such effects include students learning in isolation, with less rapport and with less personal teaching from the teacher (Vernette et al., 1986).

Some teachers see computer as disrupting established classroom routines and creating new processes on top of many already existing ones. Such established routines in most classrooms include, assigning worksheets for seat work, focusing students' attention while the teacher delivers pearl of knowledge. But with the introduction of computers (if properly used), classroom organization will be more student-centered; students are no longer required to be passive learners but active learners and good thinkers. Students are expected to master available technologies, and not just computational algorithms. Students need to work on solving problems cooperatively rather than on competing for high scores on tedious tests of pencil-and paper computation. These new organizational arrangements hinge on teachers' knowledge and organizational skills and only few will be making sacrifices to accommodate the new changes.

Researchers are constantly demanding changes in education, such as having the teacher's role change from telling to coaching or guiding, and having students engage in technology-related tasks. But most teachers seem to believe that computers and related technologies are primarily useful for lecture-type classes and not for group discussions or individualized instruction. Ironically, when much emphasis is placed on integrating technology into curriculum, some teachers are intensifying their efforts on what type of materials will be

incorporated in a technology-based instruction, while others do not even see the need for computers in the classroom except for remedial purposes.

Research has called for students "active" participation in classroom discourse. According to Cohen (1988), students must also assume more responsibility for what happens in the classroom: "It is after all, their ideas, explanations, and other encounters with the materials that become the subject-matter" (p.106). Cognitive psychologists and educational technology researchers alike feel that computers will support the revolution in education to achieve the desired result suggested by education reforms (NCTM, 1989, 1991; NRC, 1989, 1991). The challenge snags, however, on how to deal with or accommodate teachers who hold the beliefs that knowledge reside with them or exist in other sources such as textbooks and mathematics (Putnam et al., 1992) and should flow from the source to the learner.

To harness technology's ability to empower students, the classroom must provide support in several ways. For example, because classrooms are groups, teachers are faced with the task of organizing students into working units and maintaining this organization across changing conditions for several months. Teachers have preconceived notions (over the years) that computer technologies require solid technical support and strong financial commitment, which in most cases are lacking. In addition, it requires a skillful teacher, given this new learning environment to establish and enforce rules, arrange for the orderly distribution of materials, pace events to fit the bell schedules as well as interests of students, and respond rapidly to immediate contingencies. It is a commonplace that all these functions must be performed in an environment of considerable inherent complexity and unpredictability. Such unfamiliar territory requires teachers' profound knowledge and skills. Achieving cooperation in the

classroom is in part a matter of a teacher's attractiveness to students--studies of student evaluations of teachers suggest that students respond to an instructor's general culture and enthusiasm (Doyle, 1983).

Summary

In summary studies have documented the importance of knowledge and beliefs in teaching (Ball & McDiarmid, 1990; Thompson, 1992). Teachers' attitudes toward classroom organization and student interaction depend on what the classroom should look like and should be. If teachers perceive students as "passive" learners, then the organization of the classroom (with or without technology) retains the traditional classroom which prevalent in schools (NIE, 1978; Mertz, 1978; Doyle, 1986), but if teachers perceive students as "active" learners who enter the classroom with robust preconceptions about the world and how it operates (Posner, Strike, Hewson, & Gertzog, 1982) then the classroom may be organized differently to accommodate other forms of learning strategies. However, teachers' knowledge and beliefs are influenced by the constraints and opportunities in the context in which they practice. The constraints and opportunities may be perceived as residing in the contextual structural levels, such as, the classroom, school, district, and community (Doyle, 1986; Putnam et al., 1992;). Therefore, the nature of instructional materials, teachers' knowledge, beliefs, the context and content of instruction are critical factors to consider in investigating teachers' use of technology for mathematics instruction.

CHAPTER THREE

METHODOLOGY

Overview

This study was designed to provide a deeper and better understanding of why high school mathematics teachers are not using computers in mathematics instruction despite the capabilities and flexibilities of computer technology. Most studies in educational technology focused primarily on the usefulness of some mathematical software such as *Geometric Supposer* and *Mathematica* as new instructional tool that supports mathematics instruction. Such studies generally tend to investigate the effectiveness of the software, and the learning outcomes (Clement, 1981; Ganguli, 1990; Kulik et al., 1983;). Other quantitative research studies such as survey have assessed teachers' perceptions about the use of educational technology for instruction in a broader sense (Kozma & Johnson, 1991; Sheingold & Hadley, 1990). None has simultaneously examined closely the relationships between teachers' knowledge and beliefs about mathematics , teaching and learning of mathematics on one hand, and the role educational technology plays to support active learning environment, classroom management and students' interaction on the other.

This study examined deeply teachers' conceptions , thoughts, and fears, by crafting detailed interviews in as natural environment as was possible. Six

high school teachers were selected for the study from two public schools -- A and B -- within one school district. The six teachers were interviewed and observed while teaching a lesson of their choice. The names of places and people have been purposely obscured in order that their anonymity be preserved. However, the study tried to inform the reader all issues that are relevant to the research by representing the characters, places, and events faithfully.

Next subsections describe in some detail the procedures used in selecting the teachers, the site -- the social context -- and the design for data analysis. Perspective is provided by a discussion on the qualitative research method in general and the relevance of such a method to this study.

Rationale for Use of Qualitative Research

Descriptive qualitative research methods were used in this project. The qualitative research paradigm focuses on discovery, insight, and understanding from the perspective of those being studied, which offers the greatest promise of making significant contributions to knowledge base and practice of education. With qualitative analysis, one seeks to describe the situation as they existed or observed and not to confirm or deny the hypothesis proposed in the study (Schuh & Whitt, 1992). For this study, qualitative research method is preferred because, it unravels and comprehends the dynamics of social changes in the behavior of teachers who are using a new instructional tool in their classrooms (Patton, 1990).

In an attempt to understand teachers' actions and the meaning attached to such actions, I conducted in-depth interviews to get at their perceptions. The interview questions were designed to ask teachers about their knowledge,

beliefs, and practice in their own terms rather than assuming meaning from their overt behavior (Jones, 1985, p.46). Experts in qualitative inquiry suggest that qualitative research method is useful in trying to examine teachers' knowledge -- what they know about the subjects they teach, students learning, and, what they think about other strategies in order to teach (Seidman, 1991). Since my overall goal is to have a better understanding of what teachers' know and believe about what they teach and how they teach it, interacting directly with the teachers was best-suited for this task - especially when using methods that make use of human sensibilities such as interviewing, observing and analyzing (Biklen & Bogdon, 1986). For example, observing a teacher teach a class with a particular software and having the opportunity to talk with the teacher afterwards, afforded me a rich opportunity to explore the influence on, as well as the rationale for the teacher's practice. The teacher delved into a rich detail that unraveled what the teacher knows about the subject-matter, its suitability for teaching/learning and why? What the teacher considered to be the purpose of the software she has chosen for a particular topic or lesson? And in other cases where teachers never used it, I had the opportunity to know why they never considered using the technology for mathematics instruction.

An observation of actual practice reveals how different things a teacher knows and believes impact the decision making process about what to teach and the instructional strategy to adapt for any lesson. Such observations contribute importantly to the analysis of the different things that teachers know and believe--about the student, teaching, learning, subject matter, tool, and context-- and how those come together in their teaching. In observing the classroom, observations also provided a sense for the physical environment as well as the social context in which teachers interact with students. The physical

environment offered an opportunity in evaluating both the possibilities and constraints under which teachers operate, and to have a clearer picture about classroom management and the interactions between students and the teacher.

Observation also provided a lens that evaluated the type and nature of students teachers attend to and the overall classroom management, since they significantly impact on what happens in the classroom. Apart from some external factors that influence teachers decision, Thompson (1992) indicated that teachers may also be concerned with: (a) mathematical content, with emphasis on computational execution or conceptual understanding; (b) students; and/or, (c) classroom management and organization.

Despite the shortcomings associated with qualitative research methods, including their being labor intensive, and deceptively difficult -- that is being more difficult than they appear to be at first glance (Biklen & Bogdon, 1986), I preferred the qualitative approach over a survey method. The nature of my inquiry -- trying to understand what teachers' think about the use of computer in instruction and how they actually use educational technology suited the on-site observation and interview techniques of fieldwork research (Bogdon & Biklen, 1982; Hammersley & Atkinson, 1983). The qualitative method -- interviews and observations, irrespective of the sample size, produced a considerable yet manageable data that left me with the dilemma of making decisions at every juncture.

Site

The study took place in a school district located in the capital city of a state. The school district runs a medium large urban school system. Like most urban centers, the school district's population is poorer and browner than that of

the suburban communities. Because it is the state capital, a substantial percentage of minorities, middle and working class population make up the majority of the school district's families.

The school district has an estimated population of 25,000. The student population is racially and ethnically heterogeneous, with racially balanced student enrollments in all schools. There are three public high schools, out of which, two participated in this study. Schools are neat and orderly places to learn compared to schools in bigger cities. The schools' playgrounds, halls and classrooms are well kept and maintained. The school district has a long history of being a site base for research and development because of its closeness to Michigan State University (Ray-Taylor, 1991).

The school teachers are called veteran teachers. Most of the teachers have taught more than twenty years and have degrees beyond the baccalaureate level. Teachers in the school district are experienced participants in research studies. The school district sponsors an instructional academy each summer which includes 79 different workshops for teachers to further their professional growth (Ray-Taylor, 1991). Teachers in each school have strong administrative support and are empowered as a team to make decisions affecting the total educational program of their schools.

The high schools within the school district have a population of approximately 1700 students each. The schools have a computer lab used specifically for computer education, such as, programming, word processing, spreadsheet, and database management. Most mathematics teachers have at least one computer in the classroom, but none of the school has mathematics lab. Although one of the schools in the past had a mathematics computer lab which was sold by the school principal who [according to sources] needed

space and money to run the school. It is important to note that despite the resistance by the mathematics teachers, the principal went ahead and sold the mathematics computer lab anyway. However, many innovations have found their way to the classrooms, probably due to the presence of MSU and the seat of government

School A is not a professional development school (PDS) school, but has a good reputation in over all student performance. School B that participated in the study is a professional development school. As a PDS school, there are concerted efforts toward making changes in classroom practices and school organization. In collaboration with university faculty and graduate students, teachers reflect upon their practices, and work through their struggles as they create a richer learning community for students. It has a population of approximately 1650 students and two teachers were selected to participate in the study.

Teacher Selection

One of the initial challenges of this study was how to select teacher participants. First, it was not an easy task to engage high school mathematics teachers in a total of three one-hour-interview series. Second, it was even more challenging to find high school mathematics teachers who fit the criteria for the study. The criteria for teacher selection was based on the following: 1) willingness to participate in the research project; 2) being relatively open to new ideas; and 3) having the experience of teaching mathematics in high school for at least five years. One basic assumption that was made before the selection of the teachers was the teachers selected for this study were proficient teachers in terms

of their pedagogical content knowledge and teaching experience.

Finally, the teacher should be as responsive as possible in responding to the probing interview questions. This was important first, because proficient teachers were needed for the study since the conceptual framework rests on the credibility of teachers' knowledge and beliefs about mathematics, teaching/learning mathematics and the use of technology in mathematics instruction.

To select proficient teachers I relied on my earlier interactions and experience with most of the teachers that participated in the study. Fortunately, I was a substitute teacher and a volunteer in this school district and worked with all the teachers, but more closely with three of the participants, Tomia, Obed, and Robinson.

I was a substitute teacher for Tomia for six weeks. While substituting for Tomia, I shared the computer lab with Obed who eventually supervised me throughout that period. Obed volunteered to participate in this study for two reasons: first, for his genuine interest in this study, and secondly, for his experience and interest in any research study that involves the use of educational technology for instruction. I worked with Robinson in his school as a volunteer in an after-school enhancement program for a semester. The after-school enhancement program was designed to help black students who were "at risk " with mathematics . During the after-school enhancement program, Robinson served a dual role: as a volunteer and as a resource person in terms of coordinating and guiding the efforts of other volunteers. The three teachers mentioned above recommended the other teachers: Vesta, Kayce, and BeBe

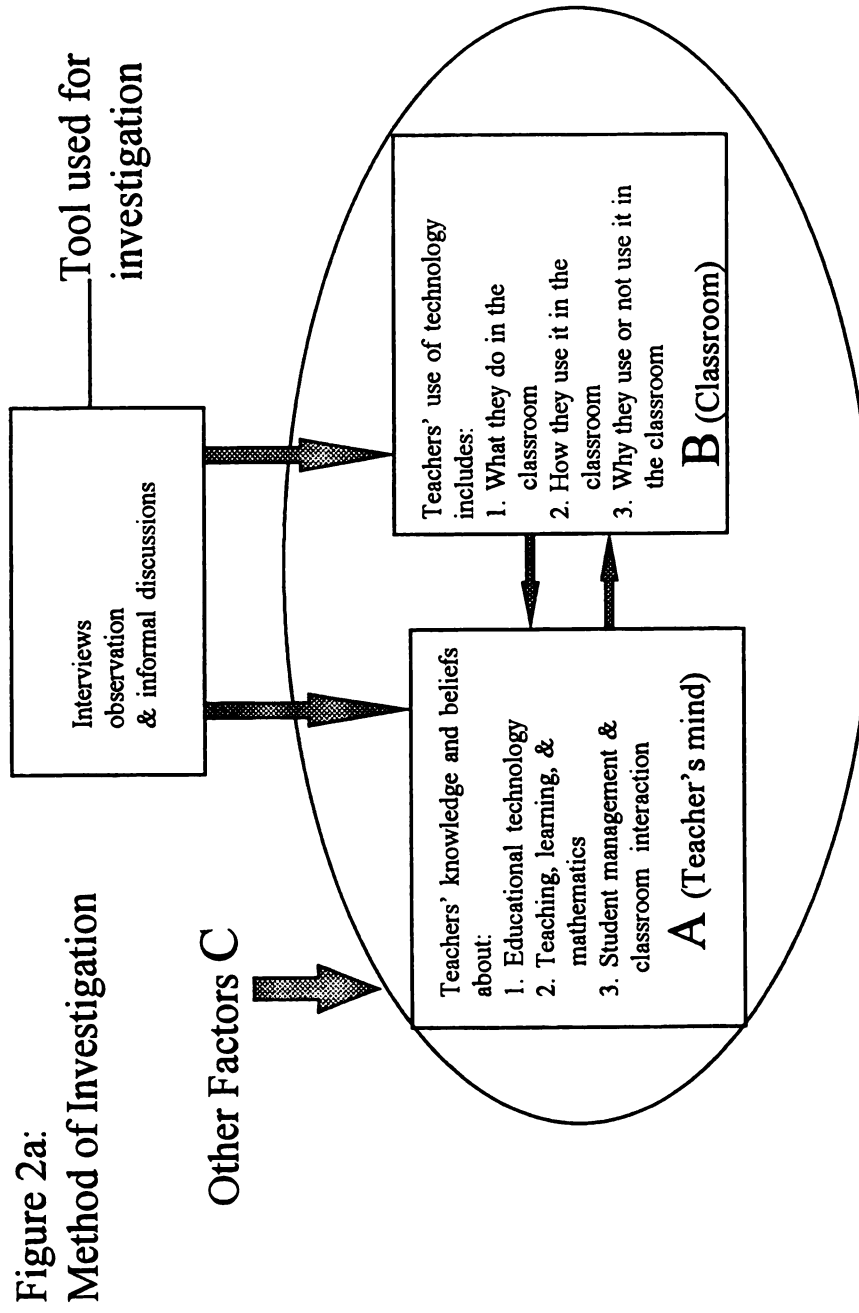
All the teachers that participated expressed interest in and a willingness to participate in the study. In recruiting the teachers for the study, I made

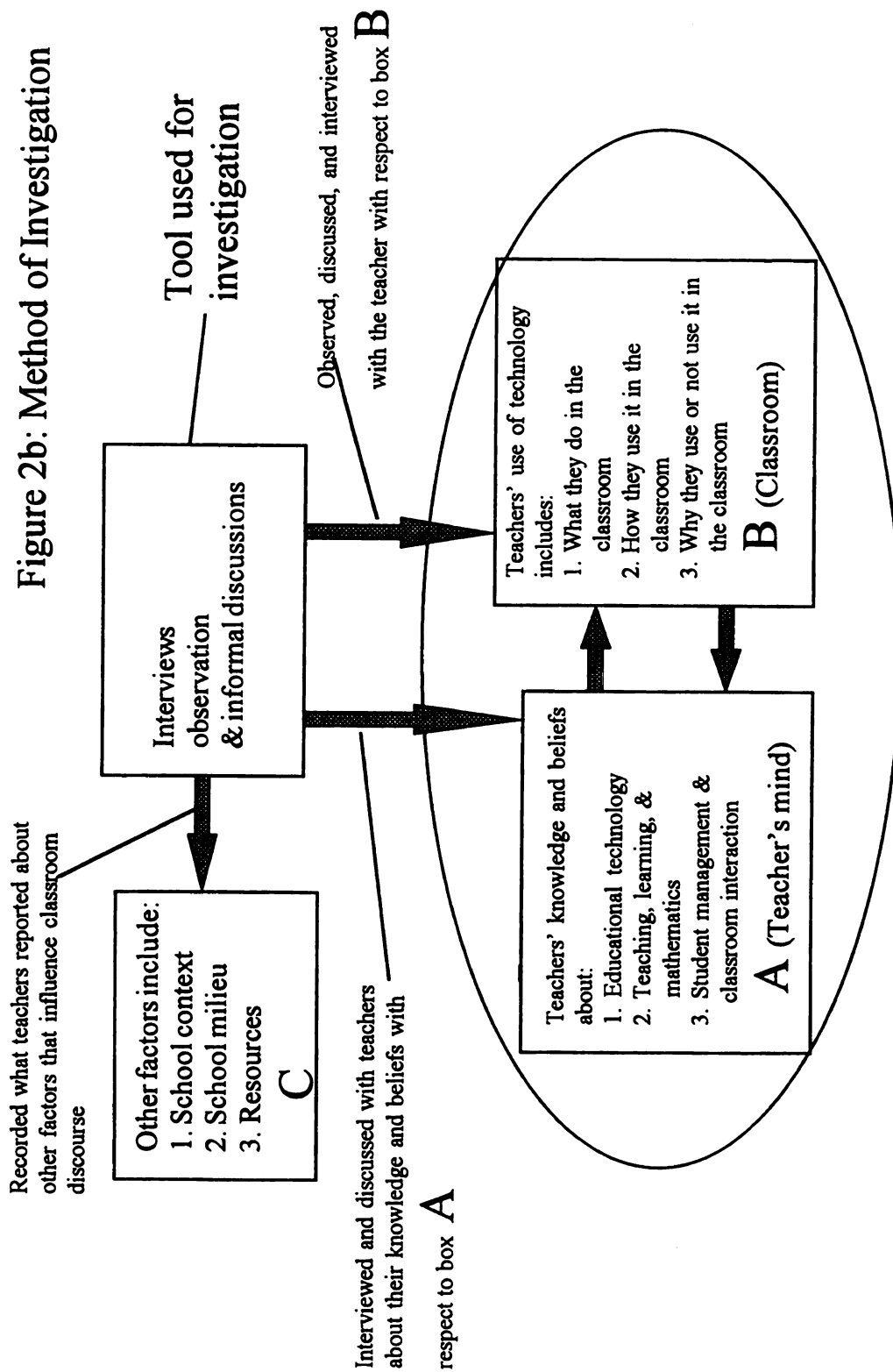
attempts to select teachers who were reported to have the reputations for making efforts toward changing their classroom activities. Most of the teachers selected for this study have taught for more than ten years and have been trying their best to change their pedagogical strategies despite pressures from other structural (external) factors as illustrated in Figure 1. Before teachers were either interviewed or observed, they read and duly signed a letter of consent (see Appendix E). The primary interview lasted approximately an hour but in some circumstances with the teachers consent it stretched more than an hour. All the interviews were conducted at the teacher's discretion and convenience. The classroom observation was during the normal classroom discourse, it never disrupted the normal classroom proceedings.

Data Collection

Data collection for this study consisted of interviews, classroom observations, and informal discussions as represented in Figures 2a and 2b. Figure 2a and Figure 2b are simplifications of the method of investigation and tools used in examining the research questions raised in Chapter One. Box A represents the mind of the teacher, B represents what happens in the classroom, and C represents other factors that influence teachers' decisions in the classroom. The main research question investigated the relationship between A and B, while the second broad question documented other external factors teachers reported that influence the decisions they make in the classroom.

The interview component consists of two segments: a pre-observational interview and a post-observational interview. The classrooms were observed and followed immediately with the post-observation interview.





The pre-observational interview-segments have two parts. The first part is an in-depth interview, whereas, the second part focused on what to expect during classroom observations. The first and primary pre-observational interview was conducted to understand what teachers' know and believe about mathematics, educational technology, teaching and learning of mathematics and the impact of technology in classroom management and students' interactions in the classroom. The second component of the pre-observational interview focused on what teachers were planning to teach in the classroom that was observed, what type of software [if any] they planned to use and why the software was chosen for the units they intended to teach. In sum the pre-observational interview covered a) teacher's background, b) teacher's views about high school mathematics , the teaching/learning of mathematics and the learner, and, c) teacher's views about the role of technology in mathematics instruction. The interview questions and format are found in Appendices A-E. The interview questions were field tested for clarity and were revised accordingly (Payne, 1951; Miles & Huberman, 1984). The initial questions for the first part of interviews were predetermined, and follow-up questions were based on the teachers' responses. The second part interview explored issues raised during the first interview and inquired about what class should be observed and why.

The questions consisted largely, hypothetical situations designed to stimulate in-depth discussions about mathematics and what should be noted in the teacher's mathematics teaching. For the observation component, each of the six teachers was observed in his or her classroom for one-hour class period. Field notes were taken during the classroom observations, and the classroom instruction was audio-taped. More detailed field notes were written up after

each classroom observation. The Observation Guide which documents the class observation is in Appendix C.

The final interview [post observational interview] conducted at the end of the class, was used to gain additional data regarding the teachers' perceptions of the influence of the classroom organization and students' interaction(s). It was an opportunity to probe in greater depth prominent themes identified during previous interviews and observations, and to bring to closure to the research process by encouraging teachers to comment on issues they believed to be interesting and important.

In addition to the formal interviews, additional information about teachers' goals, knowledge, beliefs, and practices were collected through informal discussions. Written notes were made on these informal interchanges. It is important to note that I served in all roles: as an observer, listener, recorder, facilitator of the dialogues and interviews, and analyzer of the data. Thus, I was always knowledgeable about the lessons and the context in which they occurred when listening to tapes or reading the transcripts. With multiple responsibilities of recording and observing during actual instruction, careful and detailed notes were taken. The interviews were audio-taped and transcribed.

Data Analysis

The interview transcripts and observation field notes from this study offered rich data about teachers' knowledge and beliefs about the role of educational technology in mathematics instruction. The major decision in the study after the data source were collected was how to use these rich data in an effective way in understanding the impact of teacher's knowledge and beliefs about the role of educational technology in mathematics instruction. Interviews

gave most information about teachers' knowledge and beliefs - - thus were primary source in data collection and analysis. Observation field notes and informal discussions were used to supplement and corroborate evidence provided during interviews.

The main task of the analysis was to find emergent patterns and connections in what teachers said. These connections, patterns and anomalies were discussed under major frames that emerged from four major sources: 1) the research questions; 2) . the conceptual framework; 3) interview transcripts data; and 4) documents about the nature of mathematics (NCTM, 1989, 1991; NRC, 1989; 1991; The California State Department of Education -- Mathematics Framework documents (1985, 1987, 1991) as cited in Putnam et al., 1992). In looking for these connections and patterns and frame for discussions I worked back and forth to develop general categories of teachers' beliefs and conceptions that helped in understanding and describing the data. These general categories are listed in Table 1 and reported in detail in Chapter Four.

This approach was preferred because it was the best way to portray the data and maintain the integrity of teachers' thought and feelings. From the data collected, careful substantive analyses of the responses provided platforms for discussions. The interview responses and observation notes were then examined given the relevance of the conceptual tools used in examining the thoughts and beliefs of teachers. For the purpose of analysis, I grouped conceptually related items into clusters. For example, in trying to understand teachers' knowledge about mathematics , the probing question was geared toward their educational goal for their mathematics students grounded in scenarios of classroom teaching, curricular materials without any mathematical topic. Most questions were cross-analyzed on several dimensions: conception

about mathematics and about teaching, learning and the learner; teachers' role, feelings or attitudes about mathematics, students or self, and their perceptions about the potential role of computers in mathematics education.

Table 1: General Categories for Analysis

Category	Comment
Educational Goal	Discussed what teachers feel is important mathematics for high school students to learn
Conceptions of Teaching	General views about teaching
Conceptions of Teaching Mathematics	General views about teaching mathematics in high school
Conceptions of using Technology in Mathematics Instruction	Teachers' views about the use of educational technology in teaching mathematics in high school
Conceptions of Students' Interactions and Classroom Management	Teachers' views about students learning and classroom organization and management
Teacher's Proactiveness, working to Improve Learning	Teachers' efforts toward improving students learning of mathematics
Teacher's Openness to New Ideas	Teachers' willingness to accept/try new ideas or instructional techniques

In Chapter Five, I discussed the findings using relevant major themes synthesized from the themes in Chapter Four, such as: conceptions about mathematics, teaching and learning, student, and the role of educational

technology. Each teacher's views are summarized according to these themes drawn from the conceptual framework discussed in Chapter One. Other frames for analysis used in Chapter 4 helped to construct good rich narratives about my general observations during this study and the implications for practice.

Limitations

This inquiry is limited by the sample size. Only six teachers from two high schools in one school district participated as interviewees in the research project. Because the study was constrained by a small sample, the findings may not be generalizable.

I have only used a fraction of the information gathered in my data which I considered related to the research questions. These data were only part of what actually went on in the minds of the teachers and in their classrooms. It is extremely difficult, if not impossible to represent the thoughts and opinions of the teachers in full.

The study inferred meanings from what the teachers reported. An ideally successful interpretive research would present an intelligible and articulated depiction of the setting studied. In that sense, the meaning of the word "finding" does not necessarily connote the revelation of something that had not been expected or known before. For that reason, the findings in this research may be left for further "reading into", or "interpretation" by the reader of this dissertation. A reader interested in policy issues, may interpret this study in ways that are not congruent with the conclusions of curricularist or teacher educator. Other readers are also entitled to draw their own conclusions. Another limitation is, 50% of teachers who participated in this study were cooperative because of the long-term relationship they have developed with the researcher. Perhaps short

uninformative answers and hostile behavior could have been obtained if the researcher met the teachers for the first time. The one-time classroom observation was a snapshot that could have produced a different result if the classrooms were observed more regularly.

While I attempted to maintain an unbiased and inquisitive attitude throughout the data collection and analysis phases of this study, it is unlikely that this report is entirely free of personal prejudices and convictions. Having been concerned with poor performances in mathematics for the last fifteen years, I have a strong commitment to improving mathematics teaching and learning and have a definite preference for the type of instruction which the NCTM has recommended. At the same time, I am aware that the teachers are doing their best within the confines of their knowledge about what they teach and they should be recognized and respected for their role. The goal therefore, is to seek ways of improving mathematics instruction within these constraints.

CHAPTER FOUR

TEACHER PROFILES

Overview

This chapter presents the profiles of the six teachers who participated in this study. It summarizes teachers' views about mathematics, teaching and learning mathematics, students, classroom management, and the potential role of instructional technology in mathematics. In this chapter, I analyze these views across the teachers, looking for more general patterns.

It is important to clarify certain points that are pertinent to this study before discussing the findings. First, although one of the foci of this study is in teachers' knowledge and beliefs about mathematics, it was not possible to develop thorough and complete portraits of teachers' subject-matter knowledge. Such portraits were beyond the scope of this study, given that the intent of the study was to examine connections between teachers' views of mathematics and the role of technology in mathematics instruction, and not to evaluate teachers' subject-matter knowledge per se. Second, teachers are not discredited or credited because of the views they hold; rather their views were used as basis for

examining relationships between views of subject-matter and technology.

Vesta

Vesta has taught a variety of high school mathematics courses to all grade levels (9 - 12) for 17 years. Currently, she teaches geometry to 9th and 10th graders in school A. Vesta was highly recommended for this study by her colleagues because she has played a significant role in major school reform activities, especially in mathematics and technology. She is interested in the use of innovative methods that support new pedagogical practices, and reflect mathematics as a fun and enjoyable subject. In her interview, Vesta also mentioned her interest in assisting other teachers interested in understanding and promoting meaningful ways of teaching mathematics for understanding in schools. In addition, she was eager to provide detailed feedback and explanations on issues related to the use of technology for mathematics instruction.

Educational Goal

Vesta pondered a while when asked what she thought was important for high school students to know in mathematics. Although she considered all she has been teaching to be important, her answer to the question reveals that her primary educational goal for her mathematics students is geared toward having general skills and study skills.

It is always my hope that by the procedures I use in teaching, my students will develop some organizational and study skills that will be with them even after their formal education is completed. These procedures are used with all students. For example, at the end of the session for the transition mathematics class, there are many things the students are supposed to be able to do, such as. . . to solve an equation, to be able to use all kinds of formulas, recognize and work out problems on his/her own (Interview: 4/7/94).

She also emphasized the importance of problem-solving, by which she meant primarily the "why and how" of solving mathematical problems.

Applications of mathematics and problem-solving techniques are two areas of mathematics that should be continuously taught. Also I feel that students need to know the reasons why things are done the way they are done. If we as mathematics teachers take a little bit more effort in explaining these "whys", maybe, students might know that mathematics has more meaning than they have anticipated. And if students see the value to mathematics, they may be more tolerant about working with topics in school that may seem of importance to them today (Interview: 4/7/94).

In spite of this emphasis on problem-solving in her interview Vesta's classroom instruction on the day I observed mirrored more traditional practice.

Conceptions of Teaching Mathematics

Like the mathematics reformers, Vesta believes that the traditional way of teaching is ineffective. She feels that her teaching has changed over the years as a result of her efforts to effect changes due to the increasingly diverse culture in her classroom. She considers herself to be a "change" agent, perhaps due to her active involvement in most school initiatives and innovation programs. When asked why she changed her teaching style, she said:.

Our world is not full of absolutes, . . . and students need to have as many different approaches as possible to doing something. In mathematics, over the years we've tended to isolate it to only one way of doing something, and I don't think that is right. Due to the rapid changing of the society, we cannot be set in one mode, you should be able to change or we should be able to deviate from our old style.

Vesta stands behind change initiatives that attend to the needs of non-college bound students. According to her, the curriculum is no longer responsive because the school population has changed; for instance, the majority of the school graduates are interested in jobs, and fewer

students go to college. Vesta thinks that the curriculum should be realistic in terms of preparing the students for the work force.

Our curriculum has changed and our goal has equally changed, and I'm not necessarily sure that it is for the best, because it is much more college driven. We do not have any more students going to college, we have only a few students going to college than what we had four years ago. We operate a much more rigid and highly structured curriculum, which is too bad. It is time to reflect on what we are doing district wide.We made some changes in the ninth grade curriculum, but I'm not sure whether it is working.

For Vesta, changing technologies have become central in ways she thinks about teaching mathematics. In being consistent with the goals of the mathematics reform, Vesta believes that technology is driving the society and is gradually filtering into the classroom. For Vesta, the presence of technology should revolutionize her teaching and stimulate the interest of students toward mathematics.

The society is pushing computers too far that all our lives seem to hang on it. Everything is computerized, there's no way computers will disappear in the near future. It may take a new form and easier to deal with. Some years back who would believe that calculators could be on our watches, . . . I also predict that it will soon take over education, either at the college level, but it will definitely take some of the old ones to be gone.

Vesta's graduate program, interest in research activities, and extra teaching activities have influenced her teaching in mathematics. She believes that the old method of teaching is not meeting the demands of the students. She argues that mathematics should be fun and enjoyable. And for this to happen the curriculum should be functional. " I have realized that the old way is not going to work, lecture is not going to do it, so there must be another way of doing it".

Vesta sees herself as the lighthouse of the mathematics department. She believes that she is pioneering innovative teaching in the school, and tries different strategies within her reach. Her use of these new strategies, however, is constrained by existing views of

teaching as telling -- the teacher still being looked at as the authority (Putnam et al., 1992). Vesta is aware of this tension and to her, it is difficult to depart from teaching routines established over a period of time.

I think of any of us I'm probably the only one that uses technology for instruction and. . . I think I'm the only one that has the LCD panel. Um. . . but that does not mean that they [the other mathematics teachers] don't want to. They just don't. But my biggest challenge is to know how to use the software that I've, and remembering to use it on a regular basis and using it to its best advantage.

Vesta supports the recommendation of the NCTM framework for creative teaching that promotes active learning environment. Like many committed teachers she has continually been trying to improve her teaching, partly as a former chairperson for the committee on school initiative and innovation. Her over arching concern like other integrators, was developing relevant materials for instruction. She went on

I'm pretty familiar with what the machine can do, but shaky when it comes to creating my own ideas. Managing everything that goes along with it is not an easy task, because it changes you, it changes your approach to teaching, so you've to be prepared since it demands both time and talent.

Vesta was also shaky in moving away from the traditional method of teaching. She believes that there is a new sense of awareness whenever she thinks of using computer for instruction. She thinks of the mathematics topic, the presentation of the mathematical idea, the role of computer, and the type of students. A combination of these ideas mentioned above and the hope of getting them across to students must have made her shaky. Despite her efforts, she was more of a teller than a mediator when I observed her classroom.

Conceptions of Using Technology in Mathematics Instruction

Vesta was the first chair of the Innovation Committee, and has continually shown a remarkable interest in efforts toward mathematics

reform, especially with technology. She is the only mathematics teacher who uses computers for instruction in her school.

By having the technology available, I think our curriculum can expand to areas that will allow both teachers and students not to be so stagnant. We have a lot of bright students that get squashed in high school. They had accelerated mathematics in junior high school. They had "Mathematics-O-Rama" and "Mathematics-Equations" where they had all kinds of games and competitions, but when they get to high school, we don't do anything special to keep up their demands. So, we have a lot of bright students who can pick up very quickly, and we also have the awful lot at the opposite end of the spectrum who are careless because they have very low reading level. We have students who cannot sit in a regular structured classroom.

This interview excerpt illustrates Vesta's interest in seeing all her students succeed. She thinks that the school "rigid" curriculum did not give some potential bright students the opportunity to fully develop their talents. Because Vesta was familiar with the ideas described by the NCTM (1989) *Curriculum Standards*, she stressed the need of teaching mathematics differently. This is reflected in the following excerpt from the interview in which she responded to a question about her conceptions of using computers for instruction

I would love to get to the point of using the computer for research problem in mathematics. I would like the computer to be used for cooperative learning, because two heads are better than one . . . the software that I use the most is the *Geometric Supposer* . . . I use this with my geometry classes when we work with quadrilaterals and when we are learning to do proofs. A non-mathematics computer lab would be a great asset to all teachers because there would be a place to send small groups of children to work on class projects. many of our students don't have typewriters to work on, so having computers available on the school ground for them to use would be good for them.

Conceptions of Students: Beliefs about Performance/Behavior and Classroom Discourse

A persistent theme throughout Vesta's interview and discussion is "frustration" about students' low mathematical knowledge and lack of discipline. She consistently referred to low mathematical skills:

Most of my students have very weak algebra skills, ...unfortunately, I don't have the time to sit down with them, as much as I would want to and fill-up the gaps.

Classroom discipline was another persistent theme, when it comes to students' participation. This observation was true for all teachers except Bebe, who attributed lack of discipline to teachers poor classroom management style. The level of classroom disturbance I observed in these classrooms was alarming, with greater amount of the class time being used for noise control. Overall, students rarely paid attention for more than 15 minutes.

Brophy & Good (1986) recognized teachers' perception of students and students' learning influence the type of classroom organization and interaction that occurs in the classroom, and this observation is true in Vesta's classroom. Based on her perceptions about her students, Vesta arranges her second period class differently from first period, adopting more lecture-oriented instruction. This is necessary according to Vesta because she is losing control of the students in the second hour and rest of the day, probably due to increasing violence in public schools, and teachers' limited disciplinary powers. So, Vesta only uses innovative methods in her first hour, relying on traditional methods later, because students tend to become rowdy as the day progresses and are not interested in classroom academic activities. As Vesta puts it

In my second hour I discourage groups for obvious reasons. I don't think I'll use the computers in my second hour . . . um . . . I tend to be much more traditional, just because I get frustrated when I try new things with them. . . because behavior tends to be a little worse in a non-traditional setting. Second hour is the only hour I have them on a seating chart. You have to have the right group of students who are going to sit down and watch it being done on the overhead. If you want to observe my class and see instruction being done, first hour is the best time.

Teacher As Proactive, Working to Improve Learning

Vesta values and encourages the use of a variety of tools to promote mathematical communication and build a fun and enjoyable mathematical community in her classroom. She has been doing her best in stimulating the interest of the students when she says

Over the years, many students have developed a great dislike for mathematics and I try to change the attitude by introducing them to areas of mathematics that show the importance of knowing as much mathematics as possible and by showing them that they can succeed in mathematics. My wish for them is to have a love for mathematics that would show itself in their being "sponges" that could not get enough knowledge.

Throughout the interview she goes on and on with all possible ideas of changing the way things are done. She said, for example

Mathematics curriculum is constantly changing, we must make efforts to keep up with the changes. For example, with technology changes, now we have fractions on affordable calculators, the approach that we take to teaching fractions must change.

The emphasis here on change was a reflection of the mission statement outlined in the innovation program she chaired in the past. Interestingly, Vesta is making concerted efforts toward achieving that goal, by focusing intently on what strategies to use in making mathematics enjoyable to the students. For example, she goes beyond the call of duty, (outside the school) to find software materials for most of her lessons with her personal money for the class. However, she is frustrated with what she considers the lack of school and district resources for developing materials and searching out additional resources in mathematics. In the following quote, for example, Vesta expresses her frustration with inadequate equipment in her classroom.

I have a program that's called *The Hot Dog Stand* where the students have to tell me how many hot dogs to buy....how many buns to buy.....how many napkins, silverware....those kinds of thingsto try to get through a football season. And the idea is to make money when you get through the end of that. It's a sort of problem-solving kind of thing.....So, I've used that a couple of times with the

students. I don't use it nearly as often as I'd like to, possibly, because of my disc drive'.

As a change agent, she encourages her colleagues to try new things in their classrooms. For instance, she once mentioned to her close friend that teaches social sciences,

. . . get a computer!!, borrow a computer!!! do something!!! You are saving yourself hours by having a machine where you can keep this stuff and alter it every year. . . she was hesitant at first, later played around with it for few days . . . and then, she discovered that there are couple of things she can do with it, . . . and now, she is using it a lot

Teacher Open To New Ideas

Vesta acknowledges her shortcomings in terms of limited knowledge with the use of computers for instruction, and she is open to new ideas. She is eager to see the school provide both technical expertise and resources for innovative technology in mathematics, or any type of assistance in this regard. Through her efforts, the school invited some guests to discuss "double blocking" - - an innovative instructional approach. The reason for the invited presentation was to show that 1) old method doesn't work any longer; and 2) no matter how experienced you are, there's value in trying out new ideas.

We had some guests from Reynoldsburg, Ohio, . . . a mathematics teacher who demonstrated a thing called double-blocking, which we are going to try next year. This means, you have a one year of geometry in first semester, so you have them for two hours, and second semester you go to second year algebra, it is a way to accelerate subject in one year. So we're going to try it with couple of our geometry classes. I have realized that the "old" way is not going to work, lecture is not going to do it, so there must be another way of doing it. When we asked the lady from Reynoldsburg, how is she different, she answered "the old way wasn't going to do it, you have to rethink, and when I changed my old 25-year teaching style, we got so much, covered so much in the curriculum than I ever dreamed.

Views on Teachers' Resistance to Instructional Technology

Vesta sees more than the teacher being resistant to computer for instruction. She said

The factors that are going to restrict it is financial, student responsibility toward the equipment. . . if , um. . . students come in and start abusing the machinery. . .its going to be taken away. Teachers are going to be a big factor,. . . the administration is going to be a big factor,. . . if the administration feels that technology in any area is of importance. . . then the availability of money. . .and training will be made. . . to going to take a desire of people who want use it. You can force someone to teach with computers. . .but, you also are not going to get necessarily the quality of job that you should have. . .by forcing them do it. You can't force it on the students either. You've got to make it in a way that they want to do it. . .I think those are the big deterrents to. . . what would keep them out of our systems.

Summary of Vesta's Views

The following table summarizes Vesta's views about educational goal, mathematics, teaching, learning, students, and potential role of technology in teaching and learning of mathematics.

Table 2: Summary of Vesta's views

Category	Teacher's Views/Perceptions
Educational goal	• Empowering students with general mathematical skills and study skills.
Mathematics	• Conceptual views with emphasis on general skills.

Teaching and Learning	• Strong emphasis on development of general skills, applications, and positive attitudes. • Explanations of how we know. • Exposing students to alternate ways of learning • Supports much teacher-student interaction • Treat students as responsible learners.
Students	• Students lack motivation (an accrual over the years). • Students' poor reading level affects their understanding of mathematics. • Students' behavior is a constraint in the classroom organization and discourse.
Potential role of technology in mathematics instruction	• Computers are central instructional tool of the future. • Computers will significantly change the way of teaching mathematics. • Computers will benefit students of all learning abilities.

Tomia

Like Vesta, Tomia has taught mathematics for 15 years in the same building, and three years outside the building. She has taught grades 9-12, and currently she teaches innovative curricular materials called "construction" geometry in school B. Construction geometry is an exploratory-type of geometry which is less abstract than the regular geometry because it does not cover geometric proofs. Tomia calls it "life-skill geometry" -- geometry as used in our daily lives. According to Tomia, the curriculum was designed to meet the needs of students who failed the regular geometry class. She is known as one of the few teachers who believes that "every child counts and must learn mathematics if the instruction is delivered in such a manner that appeals to the child".

In addition, Tomia teaches computer classes to 9th through 12th graders. In her computer class she teaches mostly word processing, spreadsheet, and database management. She was one of a few teachers that pioneered the establishment of a mathematics computer lab within the building. The mathematics lab does not exist anymore because the new principal sold it.

Teaching Context

Tomia teaches construction geometry to 11th & 12th graders with an average class size of 29 students. All the students in the geometry class I observed (29 of them) failed the regular geometry class. Most of the students have serious disciplinary problems that qualify them to be in special education classrooms. Tomia's biggest concern is absenteeism -- in her interview she pointed out that it is almost impossible to have the

same set of students in a class throughout the semester. When asked about the prerequisites for the class, she said,

For prerequisites all I need is,students have to be committed to coming to the class on a regular basis, and bringing their materials for studies. For now, it is tough to have them come to class regularly or even bring in their paper and pencil when coming to class. Another main issue, is for them to pay attention, because a lot of times even when you get them in class, they don't pay attention, and do not participate in the class activities.

Because construction geometry is designed for students who failed the regular geometry class, Tomia considers it to be "easier" than regular geometry, because there is not much emphasis on abstract geometric proofs. Construction geometry focuses on practical constructions where students use tools such as a compass, a straight edge, and the protractor for constructing angles or any other kind of geometric figures like circles, squares, triangles. Students in this class do a lot of constructions and examine and compare properties of those constructions. For example, they might construct various quadrilaterals and compare their properties. With congruent triangles, they do a kind of geometric proofs using concrete examples by going through the process of constructing equal triangles, showing that the triangles are equal, then the angles are equal, and the reasoning behind that.

Educational Goal

Tomia's central interest is problem-solving skills. Problem-solving was a persistent theme throughout her interviews and discussions. She reported that she spends considerable amount of time early in the year trying to engage students in mathematical discourse that attempts to extend their understanding of problem-solving and their capacity to reason and understand what they are doing. As she put it,

I usually spend like the first couple of weeks of school just talking about problem-solving and different methods of solving a problem.

She also believes that the most important skills students of mathematics should have is problem-solving skills. According to her

I think the most important thing students should learn is problem-solving, because if they learn the problem-solving skills, they can pretty much apply that overall. For example, if they come across a problem they can't perform algebraically, they should be able to come with some sort of strategies that could lead to a solution.

Conceptions of Teaching Mathematics

It is not really clear how Tomia approaches the task of teaching problem-solving especially when she reveals that her teaching style draws more on a hierarchical view of learning theory. She once said,

I prefer teaching from simple to complex, because of the type of students we have in this building.

Tomia's teaching style is highly flexible and rests on students' ability to retain. She tries to move through the class materials only as fast as students can learn. She vehemently opposes the idea of going through the textbook and covering "X-amount" of chapters without caring how much the students are learning. She supports her argument by saying

What I try to do is cover as much of the material as I can as long as the students are learning. But when I find out that the students are not making the necessary connections with what I'm teaching, . . . then, I try to back off and go over it again. . . . Usually, what happens is, although I never covered X-amount of chapters of the text, my students tend to have a better understanding than other students who covered six or more chapters.

Another probable reason why Tomia does not care about content coverage is, she does not feel the pressure other teachers face in terms of standard tests, because she teaches students who are not involved in any standard tests. The students she deals with have already taken the

MEAP test, and school does not care about the SAT score because most of the teachers never get to know how much their students performed in the test anyway.

Tomia teaches problem solving by modeling strategies as she solves some examples, and then requesting the students to follow her steps. She states,

I always do an example while the students watch, then, do another example with the students participating, and then allow them do the examples while I watch them. By so doing, they have a pretty better understanding of what is going on.

In addition, she varies her teaching style depending on what works for her class. One of the things that rekindles her teaching efforts is frequent use of computers, particularly for their motivational appeal for students. Tomia said

I think that the students also are excited, . . . they like computers, because like I said, they are used to *Sega Genesis and Nintendo* --- those are computer games. And if they see that they can be successful at it . . . they'll enjoy it.

To Tomia, students' learning is a strong theme, and she's prepared to revise or skip the curriculum as long as the students learn. It appears her main interest lies with students' accomplishments, rather than getting into more sophisticated mathematical problem-solving. Nonetheless, Tomia seems to have some satisfaction whenever her students demonstrate that they have learned something

The feeling of . . . they-have-conquered something rather than saying OK!, I covered 12 chapters of the transition mathematics textbook but when tested, . . . they flunk it. If I cover and use the same exam materials with other students and my students do as well on the exam, then I tend to stick to what works best for the students rather than following the textbook sheepishly. So, I tend to adopt/adapt the curriculum to make sure the students are learning the materials that are relevant to them and something they can relate to, than just doing it for the sake of doing it.

Tomia does not believe in her students going through a traditional set of rigid mathematical steps. She uses lot of manipulative or visual

representations to teach her Exploratory Geometry unit. Sometimes, she takes the students outside the classroom to measure an existing lawn, and allows the students to figure out what to do depending on the original design she provided. She calls it "life-skill" mathematics.

Tomia carefully plans the use of manipulatives or other representations that will help lead students to understanding. She also claims to teach the whole and wants her kinds to fill in the pieces but in a multi step-by-step fashion.

I think a lot of things we do are logic, because we don't have a prescribed problem for them [students] to do, . . . for example, look at any story-problem, or an algebraic equation, . . . it is already set up, students only figure out the solution. My students have to figure out how to set up the problem, and then arrive at the answer. A lot of times, in constructions, I might put up a design on the board and say "create so and so". Then they have to figure out what is needed to create the design, . . . that makes them think logically. I do not set up the steps for them, which is the case in regular geometry proofs.

She likes to do a variety of things to stimulate and maintain the interest of the students. In all her struggles to teach, she tries to select mathematical tasks that will engage her students' interest and intellect, but unfortunately, the students hardly get it, because their mathematical capabilities are very weak, and they hardly pay attention throughout the class.

Despite these efforts, most of her colleagues have challenged her for not following the curriculum or the textbook, and she has reacted by saying,

The students are here to learn and not to cover 12 or 15 chapters of the book. If covering 12 means learning nothing, then we're doing the wrong thing and have failed. . . defeating our main purpose of education.

A closer look at her description of *creative* teaching, however, reveals that the description does not necessarily differ from traditional teaching strategies. From my observation of Tomia's class, her efforts may

motivate students interest in learning mathematics but may not necessarily allow students to construct their own meaning nor does it promote students' inventiveness in doing mathematics through the type of mathematical tasks she provided. Her description means, students being engaged in learning the sequence of rules and procedures that could result in any meaningful mathematical discourse, because she commented that,

I tried to make the instructions on their worksheets so detailed that they could work through it without much difficulty.

Conceptions of Using Technology for Mathematics Instruction

Tomia has been teaching computer classes for years and she is the most proficient computer user of all the mathematics teachers in her school. She enjoys working with computers, and believes that computers have a lot to offer in mathematics, especially for her students, by improving their low academic level -- through individualized instruction, group learning, or cooperative learning. She also believes that teenagers are attracted to anything having to do with technology, as evidenced through their interest in computer games such as *Sega* and *Nintendo*. She wants to do more exciting things with the technology.

I decided to use the computer because the traditional method --lecture style, was not working, so I thought of doing something different. In the beginning, it was little variations such as races, going out to the hall way . . . and do some measurement, then I started using the computers. . . I have always tried to do things differently all the time, it keeps me busy and students too. I have always liked computers, and I have taught computer classes for so many years. When you start using computer for mathematics classes, you will experience that there is much to mathematics and it is fun doing mathematics.

Right now with her level of computing, she wants to do a lot more with the computers,

I would like everyone to have a computer. . . and I would like them to start out with doing some problems on the computer,. . . the problem should deal with the lesson I'm going to teach,. . . something to lead, (like a preliminary) into what I'm going to talk about.

Tomia's reason for doing that is to capture the interest of the students first, before introducing the mathematical ideas. From her experience in the computer classes, she knows how the students behave when it comes to playing or working on the computers. She feels that the computer creates a learning environment that promotes cooperative learning and individualized instruction. Worried that traditional teaching methods do not provide strategies to deal with the diverse group of students in her classroom, Tomia claims that technology will respond to students' diverse interests, cultural, and socioeconomic backgrounds in selecting her mathematical tasks. When I asked Tomia about her experience working with her students with these sorts of computer tasks, she responded:

It worked out real well, because what I did is . . . I didn't let the students to pick whom they sit with. I paired them with people . . . and tried to pair certain people that were familiar with computers with someone who wasn't. So it worked out real well, . . . what happened is,. . . the one that knew the computers would try to explain it to the other mate . . . by the time they got the knowledge of how to use the computer and then actually get on the computers . . . they knew how to interact with each other,. . . so that they could help each other with the problems . . . even if the computer person didn't know anything about the mathematics . . . they still could interact and help each other -- so that they learned the mathematics and the computers.

Tomia does not encourage drill and practice type of computer programs, because from her experience such programs quickly dampen the interest of students. She emphasized that the drill and practice software no doubt gets to students with lower mathematics abilities only if it is built around conceptually challenging problems. She believes that if students are just sitting there, doing problems as they would be writing on paper, the program will not hold their attention. Students generally

like challenges, especially if it gets to conceptual type of problems where they have to think about it -- "I like those better, because it gives them or it makes them to think harder, but at the same time provide them with immediate feedback."

You'll be surprised that even the ones with low mathematics skills still struggle to get the right answer or to have some success with programs conceptually designed.

Tomia was quick to mention the amount of time and effort that goes into the preparation of a lesson when the computer is used.

It was a lot more work than the normal class classroom. . . In the traditional setting it's easy . . . once you get the students working . . . you can just sit down . . . or go to your desk and do whatever you want to do. In the lab setting, it was hard to do so because . . . even though you had students that were together. . . they would want you to come over and see what they have accomplished or need accomplished . . . so they'd call you, "come over and see this" Or you might end up in a situation where even though I didn't try, I might end up with two students who knew nothing about the computers, so then you've to run over there and help them. And, . . . you always had to be floating around the room, so there is no time to sit back and relax . . . you'll be constantly moving around . . . but that was great for me . . . so it worked out good, but like I said it is a lot of function anyway.

One of the time consuming tasks is the selection of the software. Tomia took special interest in reading the software brochures put out by computer companies. She was current with most of the software-updates in the market. Despite her commitment to the use of computers, she acknowledged that it is both a time consuming and demanding activity.

Another big issue is the selection of the right software. Before any class, the teacher has to go through the software cabinet to select and in most cases, preview the software prior to using it in the class. It's often a heck of a job. You have to spend hours ahead of the class time, just to prepare for one lesson and type up some of the worksheets needed for the class. I recall spending good time there preparing the lesson, and typing up worksheets and getting ready, so when they come in. . . they could sit down and get started immediately. . . they didn't have to wait for instructions for me --- I tried to make the instructions on their worksheets so detailed that could work through it without much difficulty. And that is part of the reason why a lot of teachers didn't use the lab.

In sum, Tomia prefers the use of computers to traditional teaching methods. She argues that students learn more with computers than the traditional way, because computers tend to hold their interests longer

They can sit at the computers and pay attention to that computer. . for the entire class period. . .whereas, if I tried to talk for the entire class period-- after 15 minutes. . .they're gone. And it doesn't matter what you say after the 15 minutes, I would always stop to say OK here's your assignment, they may work another 15 minutes --- that still leaves 25 minutes of wasted time. ..but on the computer, they worked the whole hour.

She feels that sometime in the future around the 21st century, computers will probably come close to replacing teachers and the teacher will be more like a resource person or a facilitator as opposed to somebody getting up there lecturing and testing.

Conceptions about Students' Interaction and Classroom Management

Tomia feels good with how her students interacted with computers. As she mentioned above, students are excited with computers because anything that would guarantee success engages their attention. She argues that students nowadays believe in an immediate reward system, -- they want something done and done immediately. They are described by another teacher as "society in a hurry", and that is why, according to the teacher, their "attention span" is short. Tomia said the computer has the capability of giving them immediate feedback. She recalled her experience with the students in the mathematics lab,

Most of them loved it, but others said "I don't like computers, computers and I don't get along". . . But after they experienced some little success on the computer, the language changed to. . .this is so good

Tomia believes, however, that creating an active learning environment depends on the teacher. She contends that once students are busy there will be less distraction in the class. And that will allow

teacher's effort to be geared toward facilitating learning and useful discussion, unlike in a traditional setting where most of the time is spent controlling students and averting chaos in the classroom. In the computer lab setting, although little can be done in terms of physically rearranging the pattern of seats, students are usually engaged in any tasks assigned to them.

Teacher as Proactive, Working to Improve Learning

Tomia is one of the teachers who are tired with the direction education, especially mathematics is going -- she considers most of the students to be at *risk* of dropping into the special education class. She is working hard toward presenting mathematics in a creative way that will appeal to the students. Tomia is working to improve her teaching and making mathematics more interesting for her students. Throughout our dialogue, it was clear that Tomia is making deliberate efforts to alter her teaching style in order to serve the students better. But because of the complexity involved in keeping up with variety of novel approaches necessary in improving mathematics instruction, she acknowledges the ambiguities involved in the design of a system that sufficiently and effectively promotes or reflects her intentions for the class. She said

I would like to have a resource person -- who could categorize the software and get it ready for class purposes. For example, whenever I want to locate a software that deals with constructions, I wouldn't have to sit down and go through the cabinet searching for it. . . I think I would be more effective using the computers. All I need to do is just go out and buy all kinds of software for every topic, and let my resource person organize them for instruction

Teacher Open to New Ideas

Tomia is interested in anything that will improve teaching and learning in her classroom. She welcomes new ideas geared toward productive and enjoyable mathematics instruction.

I like to look through software books and I try to find materials that would be appropriate for the lesson if I had access to computers. Even though I don't have computers, I still look through the software books and find materials that are appropriate for my classes . . . and I try to read through the information to see exactly where I could fit in. So I know there's software out there that you can use for high school mathematics.

Tomia is on top of new products that are designed for mathematics classroom of tomorrow. She is ready to participate in any collaborative teaching and activity that will stimulate learning, reduce classroom wasted time --in terms of misbehavior and rowdiness.

Views on Teachers' Resistance to Instructional Technology

Tomia discussed teachers' general resistance to educational technology for mathematics instruction under three broad areas: (a) lack of knowledge and belief (b) lack of time (c) lack of funds and resources.

Lack of knowledge and beliefs. Tomia feels that teachers' lack of knowledge about computers is responsible for their not using computers for mathematics instruction.

I think for a large percentage of the teachers . . . it is the fear of the computer itself. For Tomia, lack of teachers' knowledge in the use of computer for mathematics instruction is responsible for the slow integration of computers in the mathematics curriculum. She described it in the following way.

Teachers hide under the cloak of other reasons to protect their image and ego when it comes dealing with what they have little or no knowledge of.

She contends that teachers will be willing to use computers if they understand what to do with them and how to use them. When the question of what she thinks about computers not being used for mathematics instruction district-wide, she repeated the following.

I think a lot of it is lack of knowledge. . . because a lot of teachers say "Oh I want to get a computer" and immediately they receive one, they realize that they don't know what to do with it. . . . there are no programs, . . . there is nothing available or any literature that said "these are some of the uses for this . For example some teachers were given the computers and some had software, and that was it, no further contact or lead on how to use it.

Secondly, according to Tomia, teachers are not prepared to change their tradition [beliefs]. They have tons of materials already prepared for all the mathematics subjects they teach. It is easy and accessible without much ado. So, most of them are not ready to learn new ways. Most are stuck with the impression that the problem lies with the students, and not with their teaching style.

They are convinced that they are doing their best to teach the students, and if the students can't get it in a regular (traditional) class, the new learning environment won't do it.

Lack of time. Tomia believes teachers feel that they are carrying too much load already. No one wants to add extra to what they have, especially when they lack the knowledge of the instructional tool. Working in a computer environment demands a lot time for preparation, and teachers claim that they don't have the time. For Tomia, that is classified as "laziness", and lack of interest in what the students are doing.

Because some of the teachers are familiar with the computers, but never did a whole lot when we had the mathematics lab. . .and if you're familiar with it and

you're not using it. . . . it must be that you don't want to take the time to prepare or the teacher feels it is time consuming.

Time is still the issue for those who are not familiar with it because they can take some time and learn how to use it,

Except they are just being lazy, or do not believe it worth the effort and energy. Teachers could become familiar with computers if they have the time by taking computer classes . . . they are always offering classes . either through in-service type programs, or, Lansing Community College, or Davenport computer classes where you can just go and get the knowledge. . . if you take at Davenport, it's free.

Lack of funds and resources. Finally, Tomia argues that computers are not generally available to teachers and students.

I think if the district would give more computers and then offer classes. . .through the district, teachers can attend . . . and have people show them how to use the computers. . .then I think they would be used more.

Even when talking about district resources, Tomia sees the teachers' role as central in moving toward greater use of computers for classroom instruction:

Even if you know how to use a computer, you still need to come with your own materials for your class. . . but if they offer some kind of in-service, or some kind of classes where the whole focus of that in-service was to teach teachers how to use computers and help them during that period of time to develop some materials to use with the computers. . .I think a lot – about 50% of the teachers would be more apt to use the computers more often. But now there is no such thing probably due to lack of fund on the part of the district/administrator or lack of interest on the part of our teachers.

Sometimes Tomia believes if the district is interested in teachers using the computer, they will be willing to find money to buy the computers.

She said,

. . . ignorance, money, and lack of knowledge. Because, I think that once people are aware of how it can be used . . .they will find the money, but right now, they claim that there's no money to buy computers.

Her concern is even nation wide. She feels that until somebody in the White House [Congress men and women] realizes that the future of

this country rests on education, there may not be any significant changes in our classrooms. She called on the policy makers to stop saying,

In Japan, the students go to school six days a week. . . . Well if they go to school six days a week, they have the resources to support that. . . . but if our students go six days a week, and we can't afford to buy calculators for them, . . . how can we expect our quality of education to improve?

Until somebody in the Oval office says "what is the difference between what the Japanese are doing over there, and what are we doing over here and say OK! this is what we need to proceed, nothing is going to happen". Her final word on this argument is,

The Congress men and women should start putting more into education instead of more into guns. . . or more money into welfare or jails. . . . because if we have the right type of education, there will not be need for welfare or law enforcement in the first place.

Summary of Tomia's Views

The following table summarizes Tomia's views about educational goal, mathematics, teaching, learning, students, and potential role of technology in teaching and learning of mathematics.

Table 3: Summary of Tomia's Views

Category	Teacher's Views/Perceptions
Educational goal	• Developing students' problem-solving skills. • Wants students to apply problem-solving skills in all aspects of mathematics.
Mathematics	• Conceptual views with emphasis on problem-solving skills.

Teaching and learning	• Strong emphasis on development of problem-solving skills, applications and positive attitudes. • Explanations of various problem-solving strategies. • Students should learn mathematical concepts designed from simple to complex tasks. • Treats students as responsible learners. • Alternate ways of teaching promotes students' "success" • Mathematical tasks should be designed to mirror students natural interest, e.g. computer games.
Students	• Every student is capable of learning mathematics, if mathematics is taught in a more meaningful way. • Biggest concern is students' lack of motivation.

Potential role of technology in mathematics instruction	• Computer is a powerful instructional tool for teaching mathematics. • Using conceptually designed instructional software makes mathematics enjoyable. • Poorly designed mathematical software, especially the drill-and-practice type, easily bores students no matter his/her mathematical skill.
--	--

Robinson

Robinson has taught mathematics for ten years including some overseas teaching. He currently teaches transition algebra and algebra 1 & 2 in school A. He was selected for this project based on his willingness to participate and has a track record of volunteering his time and expertise to programs that are geared toward raising the skills of "low" achievers, especially minority students. Robinson was instrumental to setting up an after-school enhancement program designed to help minority students with their mathematics skills after school hours. He also has interest in research projects, probably due to his academic background while in graduate school. Robinson mentioned during the interview that he belongs to the "old school" -- and he believes that nothing is wrong with the traditional practice.

Teaching Context

Robinson has a class size of 30 students. Like Tomia, all students in the transition algebra are regarded as special education students because they all failed the class the previous year and are very low in mathematics skills. The class is notorious for absenteeism, attention deficiency, and rowdiness. Most of his students behave as if they're passers-by or visitors to the mathematics class. The school recognizes the problem of his class, which is almost typical of all classes, but cannot help the situation since it is the responsibility of the school to teach such group of students in Robinson's class.

Educational Goal

Robinson claims that mathematics is an important subject that spans across every subject-matter.

I think it is important to have a solid background in mathematics. By that I mean, students should be able to go beyond the basics. Mathematics is such an important subject that correlates with so many other subjects they're going to take in life, . . .thus I believe what they are getting now is not enough.

His goal is content coverage, which is strictly driven by the curriculum, and he puts it in this way:

Well all I have mentioned here are in the curriculum, . . .because the book is the curriculum, and we teach what is in the book, therefore, there is nothing I mentioned here that came out of the blue, or , out of my own volition. . . what I want them to learn is something that is part of the curriculum. Yeah, teachers have to keep going, and do the best they can under the circumstances. The teacher is not meant to change the curriculum or delay the curriculum because of the students.

When asked why? He said,

. . . Because the teacher has to cover what he has to cover at a certain speed, and at a certain time. The curriculum we have is inflexible. We're using a book that requires the students to sit down and do pencil-and-paper exercises. You are looked upon to teach the students as required by the curriculum, if you are doing something else, you're taking a big risk.

Robinson does not like the "quality" of mathematics taught at the high school level in his district. He believes that the curriculum has been so watered down that all students get is the basics. Robinson thinks that the students are not mentally equipped for the society they belong in, because the mathematics is not sufficient to prepare them for needs of the society, especially the workplace. He said,

A lot of important things are not included in the curriculum. First of all, the curriculum has been diluted or watered down over and over again and year after year. For example, the book that we used three years ago for the same class is considered very tough now, and the book we're using now is going to be tougher than the one we're going to use in the future.

He attributed the low quality in mathematics education to the type of students they have -- students with low mathematics skills.

The reason is, the students who are coming to us have very low background in mathematics, and the trend seems to be worse as we progress toward the end of the century. Some of them have not been exposed to it at all in the elementary school.

Robinson believes that his students should acquire the mathematics skills he has taught them at the end of the semester.

At the end of the session for the transition mathematics class, there are many things the students should be able to do. For example,...a student should be able to solve an equation on his/her own; and to be able to use all kinds of formulas, recognize and work out problems.

Conceptions of Teaching Mathematics

Robinson believes in teaching as "telling" and students as "listeners."

If my teaching was concerned about equations -- solving equations, OK, that is my objective -- to teach you how to solve equation,... if I use the right method of teaching, . . . and if I give you the right exercise on solving equations...my expectations are, you should walk out with the skill of solving these equations.

He vehemently disagrees that other innovations such as computers and calculators can improve teaching or stimulate learning of mathematics.

He believes that students are responsible for their success, and it is their

responsibility to work harder and not the teacher. He justifies his emphasis of computational algorithms with his beliefs about mathematics. He argues that no matter the teaching/learning style, without rigorous mental computation on the part of the students, they will not be capable of carrying out some mathematical tasks beyond the basics. For example,

The objective tomorrow will be teaching them Pythagorean theorem, and there will be a lot of difficulty in learning it, . . . in fact, you may have the impression that the target is 100% teaching, probably 90% learning, and 10% distraction based on other factors . . . but what is happening is 10% are learning and 90% are not learning. So it doesn't matter how much time you spend on it. . . . It doesn't matter how many assignments you give, . . . it doesn't matter how much yelling you do, how much calling you do to the parents. . . . It doesn't matter what you do, they will not learn it. . . . It is just that they are not into it, they feel that they have other important things to do.

Robinson sees mathematics primarily as computational skills, which should (to some degree) be memorized. He recalled his high school days -- the "old good days", when most of the computations done nowadays on calculators were memorized by students. He argues that without the ability of memorizing some basic facts and procedures in mathematics students will not advance to higher mathematics classes. And this conception of mathematics influences his teaching. He claims,

From my experience in the area of teaching mathematics, if the students were not exposed to the rigors of doing simple level of working out simple fractions, numbers etc. mentally, he/she will not have the mental power to go beyond it.

Robinson's teaching/learning style is consistent with a hierarchical learning theory (e.g., Gagne, 1977). He believes that learners must master the basics before the complex. He places heavier emphasis on rules and procedures, and argues that understanding of complex mathematical manipulation is dependent on how much one can mentally manipulate numbers and mathematical facts. For instance, he argues that if students cannot mentally say the multiplication tables it will be

almost impossible to conceptualize any mathematical idea that involves multiplication. He said,

The facts remain, I don't see how any of these students can solve a problem/story-problem without knowing how to combine numbers on their own. There's no way students can go from number problems (without calculators) to word problems. So it seems to me there is a connection in the learning of mathematics and development, . . . the mental-development that goes from learning the numbers as facts, multiply and divide fraction, . . . before taking any step further.

Robinson is set in his mode of thinking about mathematics and mathematics teaching. In our conversations he spoke authoritatively about mathematics, teaching and learning. He was comfortable with his mathematical thinking and fascinated with the procedures/strategies he is taking. Robinson seems deeply knowledgeable about mathematics himself, but holds a narrow view about students' learning.

Conceptions of Using Technology for Mathematics Instruction

Robinson is one of the few teachers in the study who clearly feel that technology is not necessary for mathematics instruction. He recognizes the importance of technology as a computational aid at a higher level of mathematics, but not as a central tool for mathematics instruction in the high school. If given the chance, he will restrict the use of technology to remedial purposes and special education.

He was able to argue articulately about the implications of using calculators in high school. He does not believe that at the level he is teaching mathematics any technology can make a difference if the students are not mentally prepared (as discussed above). Although he acknowledges that computers are important in teaching higher

mathematics, he does not think they are useful at the high school level.

He said,

Because I have done computer mathematics . . . and I've seen the necessity for it at high-level mathematics, . . . where the tool to compute some equations are not available by hands. . . and we can only use computer to figure out what a particular line . . . or a particular curve looks like. . . because the hands cannot do it. But at the level of the high school, . . . whatever we do with computer technologies will just be computer game. And I don't see the need. . . and I don't see why they [students] will be only interested in seeing the teacher teaching, . . . they are just using computer for games.

Robinson expects his students to behave like students of the "old school" by going through the rigorous steps of rote learning. For example,

Before the days of calculators, I was expected to come to the classroom and to know how to do long-division. . . and to work out the fractions. . . to do my table facts --my multiplication table. . . it was expected of me. . . and I was able to do it. . . I was able to compute my logarithm, sine and cosine without computers and calculators. . . but now, because technology is available, as a result, students rely on technology to do work for them.

One hypothesis that might explain his rigid position is lack of knowledge about how computers might be used in teaching mathematics. A closer look at Robinson's negative attitude toward the use of technology in mathematics instruction failed to uncover its primary source. It was not clear whether a lack of knowledge of how computers might be used in teaching mathematics contributed to his firm belief of their inappropriateness in the high school mathematics classroom. In unmistakable terms, he stated

I do not believe that at the level that we're teaching mathematics, the computer is going to make a difference to the students. Unless the subject-matter is integrated with mathematics, for example, FORTRAN is computer language but highly related to mathematics, because so many problems you have to solve in FORTRAN are mathematics problems. . . . Otherwise, if you are learning the basics in mathematics, you don't need the computer. I do not even see the need for calculators, because at the level we are now, - - the students are learning how to add, multiply, divide, - - even the calculator is messing them up. They are relying too much on the calculator for doing things, and in the process they don't know how to manipulate the numbers on their own. Therefore, I don't see any need for calculators and computers unless we revise the curriculum.

From the above comment emerged two possible explanations for Robinson's rejection of technology: One hypothesis is that since Robinson's teaching is curriculum driven, and technology is not integrated into the existing curriculum, he does not believe technology is useful in his situation. This does not necessarily mean that technology would never be appropriate in the high school. Alternatively, a second hypothesis might be that Robinson's resistance to using computers and calculators stems from his belief that their use fundamentally interferes with students' ability to engage in higher-order mathematics, which they can do only after mastering the basics:

I'm of the old school, and I believe that mathematics is a subject people should learn by doing it on their own. I don't see and I still believe that students cannot learn mathematics by other means, than doing it.

Conceptions about Learning

Given his commitment to procedural mastery and computational skills, Robinson believes that students should be responsible for their learning. Watching Robinson teach suggests that his knowledge about mathematics and conceptions about teaching influenced his perception about what students should learn and how to learn. According to him, constant drill and practice and memorization is the key to learning of mathematics. For Robinson, lack of motivation is responsible for students poor performance in mathematics. Poor teaching or lack of exposure to mathematics in elementary schools coupled with poor parental responsibilities help to reduce the interest of the students. Robinson reports that

The students need first of all to be motivated and to take the learning into their own responsibility, that's what we ask them for. We have seen that just teaching

the mathematics to the students is not enough for them to learn it, therefore, the motivation will allow them to go beyond the passivity of the learning in the classroom. They have to be active learners. . . do the assignment, struggle with the problems and try to get a solution to the problem themselves. If students are engaged in doing the problems -- they are equally learning in the process.

In our conversations, Robinson's understanding of how manipulatives can help students understand mathematics was fragmented and inconsistent -- it seemed that he used more drawings or diagrams for illustration than concrete objects. A simple explanation to Robinson's choice of teaching materials might be, since he relies heavily on the textbook, he uses the drawings and diagrams presented in the textbook to teach the lesson. He argues that,

We can deal with the manipulative to help them understand mathematics, but there is nothing that can replace the students' participation. . . Mathematics is something you can learn by doing it. You can go so far with manipulative, by using concrete objects, . . . but, there's a time when you have to put concrete object aside, and deal with the problem of solving mathematics problems. We cannot save the student without the participation of the student or his/her parents. It is really up to the student to turn around.

When it comes to helping students acquire these understandings, Robinson sacrifices his time and energy (even after school hours) to help students learn. Robinson seems disappointed with the type of response he gets from the students in terms of number of assignments completed and how many "correct" answers they produce. Because of the number of low performing students, he continues to be frustrated with what he calls lack of motivation, and has decided to help only students that come up for assistance. Despite the evidence that he was making deliberate efforts in providing opportunities for his students to learn, Robinson is frustrated with the results he is getting because his students have such great needs.

The teacher is willing to sacrifice 100% of his/her time, ability, and knowledge to turn around the student, but unfortunately, the Lansing school district has so many needy students, . . . with the result that the teacher is immersed in a sea of

difficulties. In most cases, the teacher is overwhelmed....therefore, it becomes up to the students who have interest to take advantage of the teacher to turn themselves around.

In our discussions outside the classroom, Robinson feels terribly bad that the situation is deteriorating everyday. Students no longer regard school as a learning place; rather, it has become a recreational playground. He believes that most of the students only attend school because they have no better alternative, anytime they grab a job, schooling becomes a history. He thinks teacher educators or policy makers are using the issue of technology as a smoke screen instead of focusing on what he considers a fundamental problem of motivating the students. As he stated above, he's convinced that the students have already made up their minds not to pay any attention to the classroom discourse:

In fact, you may have the impression that the target is 100% teaching, probably 90% learning, and 10% distraction based on other factors . . . but what is happening is 10% are learning and 90% are not. So it doesn't matter how much time you spend on it. . . . It doesn't matter how many assignments you give, . . . it doesn't matter how much yelling you do, how much calling you do to the parents. . . . It doesn't matter what you do, they will not learn it. . . . It is just that they are not into it, they feel that they have other important things to do.

Teacher Being Reactive, Working to Survive

It was not hard to conclude that Robinson is getting fed up with his efforts, because what happens both in the classroom and school hallway are counter to his beliefs. Although he loves teaching, the nature and type of students he has are frustrating his professional goals. He feels unsuccessful in helping his students learn. He is ready to work long hours or extra hours to help students, if only the students are ready to listen, and are prepared to do the assigned exercises. Robinson does

not, however, seem prepared to re-examine the way he teaches--to alter his view of teaching as presenting information to students. He defers decisions about what should be taught to the curriculum as determined by the district. To him,

You are looked upon to teach the students as required by the curriculum, if you are doing something else, you're taking a big risk.

Robinson tends to follow the curriculum rigidly without any deviation. He does not, for example, try innovative activities to hold the interest of the students. He believes that it is his job to present the curriculum; motivation is a problem of students and their backgrounds. He thus feels powerless to influence students' motivation and learning.

Teacher as Being Rigid

Robinson is firmly committed to his teaching approach, but skeptical about innovative teaching techniques and theories of learning, arguing that what students need is clear presentation of content and hard work. To him, the teacher's role is to provide the presentation of what is to be learned; the student's role is to practice and study. Robinson tends to think there is only one way to learn mathematics and generally he is not making efforts to view learning from the perspective of individual students.

Robinson dismissed out rightly the usefulness of technology for high school mathematics instruction, and insisted that even if it is imposed on teachers, it will not be the central focus in his classroom. He said, if computers are imposed on teachers, in his class

It [computer] will be used for remedial purposes and administrative activities.

Throughout the interviews and discussions, he maintained his preconceived views about mathematics, teaching and student learning, and was not ready to welcome new ideas. He argues,

I don't see it yet. I mean we have a lot to learn as far as students' learning style is concerned. . . and it is not completely clear about what the research about intelligence says. . . it is not completely clear. But my experience in the area of teaching mathematics . . . if the students were not exposed to the rigors of doing simple level of working out fractions, table facts, numbers . . . if he's not exposed to all these. . he cannot, and does not have the mental power to go beyond it [the basics in mathematics].

Throughout our discussions a persistent theme of his bias about using computers and calculators for high school mathematics dominated the discussion.

If I have computers available and if I'm told to use the computers. . . there are certain things that we can achieve with computers. . . now we have a lot of simple software available in the market. . . we can use it to teach the students geometry, simple algebra, . . . but again my bias about computers is still the same. . . OK? And I want to use the computers as something auxiliary.

Summary of Robinson's Views

The following table summarizes Robinson's views about educational goal, mathematics, teaching, learning, students, and potential role of technology in teaching and learning of mathematics.

Table 4: Summary of Robinson's Views

Category	Teacher's Views/Perceptions
Educational goal	Content coverage, irrespective of whether students are learning.

Mathematics	• Views mathematics as sets of rules and procedures, with emphasis on computational skills. • Views current mathematics curriculum as highly watered-down, weak and having mostly factual content.
Teaching and learning	• Narrow repertoire of teaching method with no explicit mention of "how we know". • Data from assessment of students not used to modify his teaching, rather used for reward or punishment. • Rote learning -- memorization of mathematical facts is a sine-qua-non for mathematical development. • Learning is solely students' responsibility. • Treats students as receivers. • Little teacher-student interactions.
Students	• Frustrated with students misbehavior. • Students' lack of motivation is their fault. • Low expectation of students.

Potential role of computer technology in mathematics instruction	• Computers and calculators are not required (or necessary) for high school mathematics. • Computers should be restricted to drill-and-practice and remedial activities.
--	---

Bebe

Bebe is the youngest teacher that participated in this research study. This is his fifth year of teaching mathematics and he has been in this building since he started teaching. He teaches beginning algebra and advanced algebra to 9th through 12th grade in school A. He is very much involved in extracurricular activities; for example, he is the head coach for the school basketball and softball teams. He uses computers only for administrative purposes. He was highly recommended for this study by his colleagues and when I contacted him to participate, he was very willing to do so.

Teaching Context

Bebe's advanced algebra class that I observed has 25 students. It is a high-track class designed for college-bound students, based on their academic performance. The students' high performance reflected on their positive attitude and conduct when the class was observed. The class reflected a special learning environment that was obviously

different from most public schools. It was the only class I observed that stood out in terms of classroom management and good student interaction. However, Bebe has one dusty computer sitting at the remote end of the classroom. According to him, the computer is primarily used for administrative purposes such as students' grades, basketball and softball records, and other personal tasks.

Educational Goals

When I asked Bebe what he thinks is important for students to learn in high school mathematics, he said

I'm basically picking and choosing what the students need to learn and what I think they're deficient in. In the first semester, say algebra 1, I spend half the semester to teach them how to solve equations because the skill level is not that good and they are going to carry that the rest of their lives. The next is the story problem, the students hardly translate a question written in English to algebra statement.

From the above excerpt, unlike other experienced teachers confronted with the same question, Bebe did not answer the question with some clear flow of thought. However, as the interviews progressed, he mentioned some of his educational goals.

Throughout our interviews and discussions one important theme that persisted was "rigid curriculum". Bebe said the textbooks and the district's written curriculum influence what they do in the classroom, for instance

I think most of the stuff I teach is driven by curriculum, because I bounce around from one textbook to another. Another problem is time the authority or the administration set-up for our curriculum saying we need to cover X amount of stuff within this time frame, and unfortunately there is no time to teach the X-amount of things they want us to teach.

In another discussion, his goal focused on students acquiring some general mathematical skills such as solving equations; use of

calculator; functions, statistics, and trigonometry for students who go through senior mathematics, and for those who are non-college-bound, they need especially life skill type of mathematics. For example, he considered the following as important

I wish there are more life-skills mathematics taught. . . I strongly believe that algebra is important, but when it comes to such students who are not college bound, . . . I think we should offer them more life skills mathematics. . . than variables, quadratic equations, triangles. . . we ought to teach them more life skill mathematics such as, balancing of checkbook, preparation of their taxes, mortgages, car payments, electric bills etc.,. . . I wish we taught that more. One thing I feel that is important for high school graduate in mathematics is having the basic skills to solving equations. The highest (probably the ideal situation) expectation for a kid who comes through here should be ready to take Calculus 1. That means they need to know all the functions, statistics, including all the basic skills in mathematics.

It is important to note that all the important things mentioned by Bebe except the life skills, are covered by the district's written curriculum -- emphasizing his over reliance on the curriculum.

Conceptions of Teaching Mathematics

Bebe believes in students' active participation. He demonstrated that when the class was observed. He engaged students by asking questions that involved them in detailed class discussions. When asked what he does to help students achieve his educational goals, he responded as follows.

I don't know if you'd call it "quizzing" or I just. . . I like to turn the questions around, so I'm asking the students. . . instead of them asking me. So, when it gets quiet and silent, I turn around and I'll start asking the questions out. And then. . . , I'll find if they know. . . And if they don't, then, I turn it more into a discussion. . . .I'll get somebody else involved in it. Well, what do you think? Can you answer that question? . . . They'll say "No", and I'll say, . . . Well, why didn't you ask ---when I asked if there were any questions. So, I try to turn it around and I,. . . .I bounce around the room. . . .I just don't pick on the students . . . ,I just ask students that I think know the question,. . . I'm asking students whom I think don't know it. And then, that way, I get more of a class discussion going.

Bebe indicated his interest in using various teaching strategies because of his diverse group of students. He wants to change the way he teaches --making himself more of a facilitator than a lecturer. In continuation with his argument, he believes that there are several ways of presenting ideas to students. When asked what would be his advice to new mathematics teachers, he suggested the following:

My advice to any young teacher coming to teach now is to be prepared, because there is no one way to teaching. You have to be flexible, adaptable and adjustable to methods.

Bebe's approach to mathematics teaching depends on the "quality" of the students. His general approach is teaching the "whole" or the more difficult concepts first, and later fill in the pieces or parts, especially to students in his advanced algebra class. But he changes his teaching style when it comes to students with low mathematical skills. For example, in his algebra 1 class (where all the students failed the class the previous year), Bebe teaches the basic mathematics skills first and builds on those -- from simple to complex. His reasoning is that students failed the class because their skills were so low that they could not handle complex or more difficult problems. This belief is consistent with most mathematics teachers who believe that mathematical concepts can be understood by students only after they have mastered basic skills, or by more able students.

It depends on the class I teach, . . .for example. all the students in this class failed algebra [the class was in session, when I interviewed, and not the class I observed]. . . In this situation I prefer teaching from simple to more complex. But in the other class [the one I observed -- the enriched class -- where every kid had an A+], I throw out the hard stuff first, or I teach the whole and fill in the pieces later. In that class, I prefer teaching the hard stuff and most of them (the students) will probably decipher it, . . . and those who can't get at the first shot, will probably pick it up eventually. . . then we discuss the little tidbits later.

Conceptions of Using Technology in Mathematics Instruction

Bebe is an advocate of using computers in mathematics instruction, but surprisingly, he has made no effort to use the computer in mathematics instruction. He has great ideas of what could be done with computers, such as cooperative learning and individualized instruction, but has not tried out his ideas. His reason for not using computer in his classes is that the only computer in his room was not adequate for class instruction. Among his needs are one computer for every student in his class. When asked how he thinks computer should be used for mathematics instruction in high school, his response was

The perfect situation will be every student to have a computer . . . and we have the network setup so the students could be self paced . . . to go through all the instructional objectives and things that the curriculum has setup for them. So they know on the first day of class that this amount of material has to be done at this amount of time-line . . . and they can pace themselves to work at their own speed and the teacher would be more of a facilitator. They would walk around the room and help students. [Another reason is]. . . I think it will be very helpful as far as diagrams, pictures, that show movement and a lot of visual representations. . . sometimes students don't see certain situations solved mathematically, but if you give them a story or a visual picture to demonstrate some mathematical problems, students are likely to follow it easily, bearing in mind that their biggest problem is understanding the mathematics language.

Bebe is aware of the complexity and type of students he has. His classes run from the "best" students to "weakest" students. He wants the computer to meet the needs of each student. For example, he said

I would like to see some type of program set up as a supplementary tool for homework problems that we are doing. So if a kid is struggling with a homework assignment in a certain area, you could pull up the computer to produce ten practice problems right away and the kid could sit down during lunch or after school to do them.

Bebe also thinks that the computer is beneficial to shy students who seldomly express their ideas in a normal class setting. To him, the computer will provide the learning environment that will encourage such students. During one of our discussions he said the following.

Because I think students are somewhat driven. . .they're afraid to express their feelings and they have attitudes about problems because of failure in a group setting. . . to where if they're working by themselves at a computer. . . the one who knows is them [the computer protects their secrecy]. Because they're the only one looking at the screen.

In spite of these grand visions of how he would like to use computers, Bebe does not use computers at all in his instruction, arguing that the equipment he has is woefully inadequate. But this view is inconsistent with the views of many teachers who are currently using computers for instruction. They would argue that if a teacher is interested, he will always manage whatever is available to him or her or approach the district for additional material resources.

Conceptions of Students' Learning

Bebe has the impression that the rigid curriculum impacts both teaching and learning of mathematics in high school. He thinks that the MEAP test also affects what happens in the classroom too, admitting that this was probably not the most efficient way of promoting students' learning:

Because they're basically laying the law down that our students must pass the MEAP test, so we're teaching students the skills needed to pass the MEAP test - and that is taking a higher priority than anything else.

Another important consistent theme is "weak mathematics skills". It seems to be a commonplace that he spends considerable amount of time upgrading the skills of the students to enable them perform in his classroom. This is consistent with other studies that suggest that students with low mathematical skills are rarely exposed to deeper mathematical thinking. Therefore, like Robinson, Bebe's pedagogical strategies seem

rooted in a hierarchical learning theory -- from simple basic skills to more complex skills. For instance, he said this about his algebra 1 class:

Um. . . first semester for algebra 1, the first thing that we spend probably half the semester on, is, I teach them how to solve equations - - because their skills level is not that good. And it is something they got to carry on the rest of the way. And so we concentrate on that extensively -- for about nine straight weeks. . . .And once we go through that, we get into probably the second thing, would be story problems. Because students have a hard time being able to read question which is written in English and translated to an algebra statement. Those are probably two of the hardest things.

Bebe believes that students are poor mathematics learners because their reading level is very low, and most of the students find it difficult to prepare informative class notes. He is the only teacher that associated mathematics students' poor performance with their weak language skills. He observed that:

One of the harder things I find in kids' learning, is class notes. As far as learning skill is concerned, they watch the teacher go over problems, do the explanation and it seems easy as the teacher is doing it, but allow them to do the same thing after two hours, you'll discover that they have lost it, because it is absolutely difficult for them to keep good and comprehensible class notes. Again I think they have retention problems too. Most of the students have a hard time to understand word problems because their reading level is very low. . . . I guess the reading level must be very low because the books we use are user friendly, . . . and they have a difficult time comprehending the material in the book.

It is important to note that during his class observation, our discussions, and interviews, Bebe's class was absolutely quiet, a rare thing to observe in any of the public schools within the district. Rowdiness and disruptive behavior is a major district wide problem that restricts effective teaching and learning in most classrooms. According to Bebe, good behavior was typical of all his classes, despite the level of students and diversity of the class in terms of race, gender and socioeconomic structure. Bebe claimed that the issue of lack of discipline is the fault of the teacher.

Teacher Being Proactive, Working to Improve Learning

From my classroom observation Bebe does not seem to believe in the tradition of teacher telling and students listening, and feels strongly that mathematics should engage the interests of the learners. One way of changing the tradition according to him was for the district to give a mandate to all teachers and say

The school authority should take a hard line, saying if you want to teach, you should have this skill, if you don't have this you are out of job.

Bebe considers computer to be one of the viable options of improving teaching/learning of mathematics in high school, and he's prepared to go back to school in order to pick up the skills of using it effectively. His approach to that is:

I think the first demand should fall on the teachers. I think majority of the teachers (including me) probably are not computer literate per se. I was on the borderline when computers started getting into the college. I got a little bit of computers while in college, but not to the extent of being comfortable with it, because of my poor knowledge in this field. Therefore I will not feel comfortable teaching it with the knowledge I have now. The old teacher clientele might not want to change their old ways of teaching. To teach with computers, I would personally like to go back to school for it.

Evidence from what his colleagues said about him suggested that Bebe is proactive toward creative ways of improving the teaching and learning of mathematics. However, he strongly argued that for any innovation to succeed, the curriculum must be revised and restructured. To him, the present curriculum does not give them the flexibility to use outside materials that engage students and hold their attention -- the curriculum presents mathematics as a fixed domain. He believes that for any meaningful change to occur in mathematics classrooms, curriculum developers should revise the curriculum. When asked what he thought

about his educational goals, and why all the things he wants his students to learn are important, he responded:

Um. . . I think it's more driven by the curriculum. . . . 'cause I bounce around from one text. I have two different textbooks. So I'm basically picking and choosing what I want them to learn and what I think they're deficient in.

It seems there are inconsistent views expressed by him toward the non-flexibility of the curriculum. For instance, he said it was mandatory for teachers to strictly follow the curriculum, when asked what stops teachers from teaching those skills that are important but not covered by the curriculum. On the other hand, in another discussion he commented that he could do something like "pick and choose". When I probed with this question, "so you have the flexibility of not using the curriculum or use something you feel that is important"? He answered "yes". At that juncture, it was not clear whether the problem lies with the curriculum -- as being rigid, or with teachers that refused to develop materials that could engage students in a more meaningful mathematical discourse.

Summary of Bebe's Views

The following table summarizes Bebe's views about educational goal, mathematics, teaching, learning, students, and potential role of technology in teaching and learning of mathematics.

Table 5: Summary of Bebe's Views

Category	Teacher's Views/Perceptions
Educational goal	• Increasing college-bound students' computational skills. • Developing non-college bound students' "life" mathematical skills, such as check balancing, interest rates, home purchase, etc.
Mathematics	• Views mathematics as a "rigid" sets of rules and procedures, with emphasis on computational skills and life skills. • Prefers flexible curriculum.
Teaching and learning	• Rich repertoire of teaching methods. • Presenting "big" mathematical concepts first to college-bound students. • Questions students' understanding and reasoning. • Treats students as responsible learners. • Treats college bound students as responsible learners. • Treats non-college bound students as receivers. • Much teacher-student interaction. • Wants students to direct their learning, while teacher acts as a facilitator.

Students	• Perceives students differently based on their mathematical ability. • Students' classroom behavior reflects teacher's classroom management style.
Potential role of computer technology in mathematics instruction	• Advocates a computer for each student. • Individualized instruction. • Computers help capture graphical representation, and abstract mathematics. • Low mathematical achievers need drill-and-practice. • Replace textbooks with computers.

Kayce

Kayce is a veteran mathematics teacher in school A with 28 years of teaching experience. He has taught mathematics and computer classes in junior and high schools. He was recommended for this study by his colleagues because of his teaching experience and open mind -- always ready to air his views on matters that affect the school system. During an interview, he stressed that his recommendations and feedback about change process in mathematics instruction was for the future generation and younger teachers because he's on his way out of teaching. He is very much attached to the old tradition of teaching, and the most persistent theme was, " I'm of the old school."

Teaching Context

Kayce has a strong religious background and grew up in a small town in South Dakota reputed for work ethics. His knowledge and beliefs about teaching and learning are highly influenced by his Christian faith. According to him, teaching/learning lost its place since the mainstreaming of minorities into the school system, and the restriction of corporal punishment. Since teachers were stripped of their authority, education in public schools has come to a halt.

Kayce has 33 students in his transition algebra class, approximately 50% of them are minorities. All the students are repeaters -- they failed the class before. It was the rowdiest class I observed, and there was hardly any teaching or learning that occurred for the whole period. Kayce spent most of the class time maintaining order. He admitted that it is typical of all his classes. One possible explanation could be that he is highly frustrated and has given up because his retirement is less than a year from the date of our discussion.

Educational Goals

Kayce thinks that it is important for students to focus more on the "process" of doing mathematics than the "product". He described the process as:

I am interested in the process and not the result. Process to me . . . is sequential steps, rules and procedures to follow. Unfortunately, . . . most of it does not run in the minds of the students, they don't make connections, because they do not take time to reflect on what they're dealing with. Most of it goes to what their eyes see me write down, . . . they write down on their papers, so, they haven't run it through their minds. . . so it becomes part of them. I just don't think that's what I think "real" learning should be. Students believe "answer" is the main thing, that is why we're all jacked out of the position in what is important. They don't know the importance of learning. . . . You have to understand the concept -- not just the answer, 'cause I'm not going to have those same numbers in the test. To me what

is important is the concept, and that is why we cut out the answers from the test book.

Thus, Kayce's goals for students seem reminiscent of an information-processing perspective, with an emphasis on learning mental processes and on developing understandings rather than just learning procedures.

Conceptions of Teaching Mathematics

As I mentioned above, Kayce believes in being in control of the class. He's a strong advocate of the "old" tradition -- holding a narrow view of teaching as telling and students as listeners. Kayce thinks that the teacher should control the class, and students should participate by listening. He said,

This class is typical of the way I teach. I did the same thing four hours ago, I stood in front of the class, went over a worksheet with four different classes. . . So it's somewhat typical, I tried to run the control of the class from the front today, usually, if you get a uniform worksheet in front of the whole class, you get a little participation out of everybody.

After listening to the teacher present an idea or procedure, it is the students' responsibilities to decipher through their own efforts -- by reading extra materials and doing home assignments, then figure out what transpired in class. If they encounter any difficulty, it is their responsibility to ask questions. But unfortunately, this is not happening -- students are no longer interested in learning and this poor attitude to learning bothers Kayce.

To him cooperative learning does not work for students; it may be possible with adults but not in high school. He vehemently argues that learning does not occur in cooperative learning. His argument is

Well it seems that when I tried groups (and very little in my teaching career) . . . I lost control. Not that I have control, but you lose control. Right? . . . but I've never found it successful. I am not convinced that there's any learning going on in groups -- that's my bottom line. . . may be, given the type of setting we've, [Why?]

Yeah in high school, we have five classes with different sizes, bursting in and out . . . here's a physical problem and too much turmoil. but it may work with adults. As opposed to elementary school teacher who has one class all day --- can group the students in anyway he/she wants. Secondly, I've not seen enough evidence to show learning takes place in a group as against the whole group. I try to adhere to the whole group, tied unto the fact that I'm not the primary source, the book is the primary source to get information from. Although it may seem more appropriate or nice to get a share of information from the group, but, I have never experienced it and I don't know whether it ever happens.

Kayce believes in teaching the mathematical process and expects students to run the process through their minds and make sense of what the process is all about. His frustration hinges on students' lack of interest. Hence he said,

Well I think in general, students just don't have interest. Or, don't care . . . don't know what learning means. . . they don't.

However, he thinks that students should have the prerequisites before they can cope with complex skills, or processes. For example, he feels that addition and subtraction of fractions is fundamental for a strong mathematical base, and has been a barrier to students' progress in mathematics. He said

Students anytime they see fractions, they just. . . clam-up. I mean these are lower level students, you know, . . . they just never comprehend the addition and subtraction of fractions. They just really have trouble with that. If you were in seventh-grade, and we say. . . until you can learn the fractions you're not going to the eight-grade, you may never get any further -- you'll die there. . . you hit the wall there. Yeah, but we keep passing them, and they get into here and I keep being frustrated because I'm teaching. . . their mathematical problem is compounded with fractions when that shouldn't be the problem.

From the above statement and my interactions with him, it was evident that he leans toward a hierarchical view of learning.

Students' negative attitudes have forced Kayce to change his teaching style. The most he has done in terms of creative teaching is to stimulate their interests, which he claimed he did with some difficulty

Yeah!. . . I tried to think of things that I can do that would stimulate their interests, but you get so frustrated with trying things new, you just. . . throw up your hands and say. . . We're going to do. . . the 'normal' thing. . . I get frustrated and say. . . why

try? I'm just going to teach the curriculum that's supposed to be taught. . .and just keep going. And you'll catch a few of 'em who'll pass and most will fail.

Because Kayce does not want to compromise his beliefs about what teaching/learning of mathematics is, he reached a compromise of adjusting his teaching to fit the present state of his classroom. That was not intended to improve teaching or learning of mathematics, but to accommodate his level of frustration. An example that typically describes his class concerns is a student eating while teaching was going on in his class. Kayce responded

Well. . .this [eating in the class] has become so prevalent that I just sort of. . .teach-over it. You ought to. . . as I mentioned earlier, it ought to be handled. But, it gets to be. . .every hour that you got to handle it, so after a while, I just say. . .the grade is the. . .carrot. If they don't want the carrot. . .do whatever you want. I'm just going to keep teaching. You know?

Conceptions of Using Technology in Mathematics Instruction

Kayce has considerable knowledge in computer programming and has taught computer classes in the past. He thinks that computer is important in mathematics instruction but should be used for "drill and practice" and "individualized learning". Also he wants the curriculum to be revised if computers will be used in mathematics instruction. Kayce puts it this way

Computer is important for various reasons, but in terms of using it for mathematics instruction I think something has to be done. Right now, it will only be used for drill and practice, and that is what most of our students need. We should inter-link with other schools in order to share some useful information. Another important part is individualized learning, helping students find some information on their own, . . . to allow them find various versions of the tests and work at their own rate.

He feels that for computer revolution to take place in the classroom, teachers are the ones to lead the revolution. He suggested that,

Top-down doesn't work. It should come from the teachers, whereby the teachers should say, "we want this and that". For any meaningful integration of the computers, the approach should be bottom-up. . The district can say, 'do this or that', but it doesn't happen. You cannot force it down on teachers, because they have some academic freedom. And regardless of whether the computers are sitting in the room or not , they're probably going to revert to their old method anyway.

Kayce has strong interest in the use of technology in teaching and he claims he has creative ideas for using it for instruction. The word "creative" does not mirror the meaning described in the NCTM documents. In another sweep, he discussed what the district or education reformers need to do for successful integration of technology into the curriculum. The following excerpt describes how the computer should be used in teaching.

I have very little idea of how students would learn with computers, other than remedial work. Characterization of best computer use would be having their test on the program, some drill exercises, monitoring attendance record. Keeping up with the remedial test has been a problem, so if I can use it for that purpose, that would be very helpful.

Kayce has a view of how teachers could be trained. His views about teachers following the footsteps of their own teachers is consistent with Ball's (1988a) findings. He said

Unless you provide some inter-mingling process with teachers, for example, let some teachers go to the university or Community college for three months for concentrated study on how to use this tool, and allow someone to fill in for that teacher, then I think you can get some changes happening. By this way, the district and university will take some of the cost. This is the only way I see things could happen because the curriculum got to be this way, and teachers will always do what he's comfortable with, unless he's comfortable with the new process. The training should make the teachers use the computer as they use the textbook. I'm a teacher because I observed someone writing on the board while I was in school, and believed that is the only way to do it. So it will not happen until teachers are trained and it becomes second nature to them.

Conceptions of Learning

Kayce believes that students should be responsible for their learning. But nothing close to his expectation goes on in the classroom,

because students are not interested in learning, especially mathematics.

He said students keep asking "why should I learn this?" and his response is the following.

You can show the importance, but that's supposing that it's going to be important to every kid. You've got 30 students out there. . . may be you say, this is "important", because . . . you have to know how to read a micrometer, when you're measuring shafts at the factory or in a mechanic's shop. . . Well you might touch two students. The rest of them may say, "Well, who cares about that". So you ought to mention a lot of fields, but it is hard to name fields that will cover all students. I think you get discouraged after a while, 'cause some of them keep saying, "well who cares? That's the attitude of most of the students.

But he acknowledged that he has not spent enough time explaining the importance of mathematics to students and why it is important for them to learn the subject. So, to the students, it is a bunch of abstract facts that have no relevance to their lives..

Kayce, like Robinson has a preconceived idea about what the students are capable of learning or not. Let us consider the following dialogue

Clifford [Researcher]: Since you know that the students have not learned anything and according to you, fraction for instance, is important in their academic life, if you teach fraction for understanding, what will happen if that means going outside the curriculum?

Kayce: Nothing.

Clifford: Then, why is it teachers are not doing that?

Kayce: Because it doesn't happen anyway. You can go back to whatever you want to teach, very fundamentally, you won't get any more participation. Now, maybe there's a point. . . these students you're seeing in the room are students that failed last semester.. . OK. . . so why did they fail?. . . because they got bad habits. . . as much as anything. There's a few of them, maybe two or three that don't have the mentality. But most of them failed because they had bad attendance records, bad study habits and so that's cumulative -- they have done that for 5-6 years. They're not just one year at this school, they've done that most of their years. . . so they are turned- off by learning.

Teacher as Reactive, Working to Survive

With Kayce's 28 years of teaching, retirement is what matters to him. According to him, he has limited time to teach. To him, his physical presence seems to matter, because in principle, he's tired of the school system, the attitude of the students, and the way quality of education is deteriorating every second. He strongly believes that "actual" learning takes place at home, the school is where one "picks" the information. He stated in clear terms that

I believe learning takes place at home. These students come to the class ill-prepared for school. But I do think the society has a role to play, but I think -- that goes right back to the home. I think learning takes place at home. . . You and me learned to do multiplication at home and I learned to do extra reading at home. . . I don't think that was our problem [then]. . I believe that students who do not learn at home are forever behind in the system. Since students are not ready to learn, and they are pre-occupied with bad attitude/behavior -- in discipline issues, I find it difficult to perform at my level best. All I do is to structure teaching to fit into their needs [no longer the needs of education], because you get frustrated after a while. People say I'm so lenient, but what do you do if the same offense is committed everyday, every hour, there's the tendency to yield to the pressure and unfortunately, I'm not prepared for this. I hope the younger ones will fix it.

Teacher as Being Rigid

Kayce consistently maintained that he is different from other teachers because of his background -- being an outsider and from a state known for work ethics. The following excerpt supports his claim as being "different"

I am not like any other teacher in this district, because I came from another little state and encountered a different society here in this city ... that's a world apart. I came from a work ethic South Dakota. They have the lowest paid teachers in the United States, but some of the highest output of students. This is true because the students over there have work ethics. I do not do a very good job with students that do not have any work ethics.

Summary of Kayce's Views

The following table summarizes Kayce's views about educational goal, mathematics, teaching, learning, students, and potential role of technology in teaching and learning of mathematics.

Table 6: Summary of Kayce's Views

Category	Teacher's Views/Perceptions
Educational goal	• Empower students with strong mathematical-thought-process skills. • Strong emphasis on understanding the mathematical processes.
Mathematics	• Views mathematics as organized hierarchical tasks [from basic facts to abstract thinking], composed of "rigid" sets of rules and procedures. • Addition and subtraction of fractions constitute the foundation of high school mathematics.

Teaching and learning	• Narrow repertoire of teaching method. • Treats students as receivers. • Little teacher-student interaction. • Assessment data not used to modify teaching. • Views learning as information processing. • Student's responsibility to develop study skills. • Hierarchical learning, from simple to complex. • No learning occurs in groups, teams, or cooperative learning, at least at the high school level. Teacher loses control during group learning. • Physical environment/school structure does not support group work or re-arrangement of the classroom for any cooperative learning.
Students	• Low expectation of students. • Highly frustrated with students' misbehavior and tardiness. • Assessment data as "carrot" to keep the students in class.

Potential role of computer technology in mathematics instruction	• Computers for drill-and-practice and remedial activities. • School is not ready for computers in mathematics instruction for the following reasons: • “bottom-up” interest (teachers requesting computers and not vice versa) • training for teachers • all schools on network • Computers as primary source of information and not necessarily as central tool for mathematics instruction.
---	---

Obed

Obed is also a veteran teacher with 23 years of teaching experience. He is not a mathematics teacher, but has been teaching computer classes for more than 10 years in school B. He is an English teacher but has been instrumental to both technology diffusion and adoption in his school. He was selected for this study because I have taught under his supervision as a substitute teacher, and due to his unflinching interest in educational technology. For example, he was one of the proponents of the mathematics lab in school B, and has helped mathematics teachers to develop materials for instruction. He has

extensively used the spreadsheet to teach some life skills in mathematics.

He is considered an independent observer, and his comments and feedback on issues about mathematics are only used to corroborate the expressed views of the five mathematics teachers.

Conceptions of Teaching Mathematics

Though Obed is not a mathematics teacher, he has associated closely with mathematics teachers for more than 20 years. He holds a strong view that the type of mathematics offered in high school is no longer educating the students. He strongly recommends that mathematics teachers should change their traditional style of teaching, because of what he calls the “changing” society. When asked to comment about his conceptions on mathematics teaching in high school, he said

Mathematics teachers should learn how to teach first before using the computers. They should learn how to teach ideas, and concepts -- let the students be comfortable with the concepts and then go over to the computer for the mathematics problems.

Obed talked about group work, non-routine problem situations, and multiple representations as powerful ways to explore mathematics and construct mathematical knowledge. He feels that most teachers are not doing that because of their limited knowledge about the subject-matter. In one of our discussions, he tried to establish that teachers have to know enough of the subject in order to make it interesting or enjoyable. He argues that if a teacher is in love with his or her subject-matter, definitely, he or she will try to present it in an enjoyable manner to his students. He said

We have mathematics teachers who demand so much homework that the students are swamped to the point of hating anything mathematics. Even smart and bright students who ought to enjoy mathematics are turned off by the number of assignments they do. I enjoy concepts and not 20 problems a night. I have good experience with graphs. Students who understand the concepts pretty well, after they're done with the formulas, do better with graphs. The important thing is to get the concept and lay-in the formula and fill down with the computer and see if it works. The computer is just a tool.

Obed is particularly creative in incorporating technology with other content areas. He taught series of lessons that merged mathematics with other social studies. For example, he uses the spreadsheet to design banking accounts for imaginary employees in a story lesson, or uses a combination of spreadsheet and database management to develop an ecology lesson for a biology class. He has a strong interest in the use of technology in teaching and encourages every teacher to give it a try. Recently, he setup a computer for his fellow English teachers, and regretted that the mathematics lab was sold. When asked what attracted him to the use of computers, he said

In my own case I was fascinated with computers, I wanted to learn about them. About eight years ago I decided to teach a class, I moved through three computer networks, so I wanted to be smart in that area and I was hooked on it. But across the population a small percentage get hooked, some are dragged, and the rest never wanted to be associated with it. Diverse reasons for diverse people.

Conceptions of Using Technology in Mathematics Instruction

Obed sees computer as a fascinating medium for instruction that could serve the mathematics teachers better in the teaching of mathematics. He supports the use of technology in a more meaningful way -- in ways that will stimulate both the interest of the students and promote active participation and learning. He humorously suggested that

I think the ultimate use of the computer as an extension of the mind is for the student to invent on his own new knowledge and use the computer as a tool to help him/her think or even as a note-taker. There should be software that allows students to approach the concepts in little steps, and eventually does the whole

concept, with himself/herself modeling. However, there are essential thinking processes that have to occur, and some of them are best communicated person-to-person, rather than machine-to-person.

Throughout our discussions, he tempered the use of computers with caution.

Common sense is important because it depends on the personality of the teacher and how he/she handles it. Every technology is a tool, and can be used well or badly. The balance in high school is between order and chaos. Between serious learning that drives people crazy and a little bit of release and friendliness.

In recommending the technology specifically for mathematics instruction, he said

In mathematics, by using some of the languages such as PASCAL, basic and I've done this myself. I've laid out equations and then let the program solve the equation. The problem in teaching mathematics, as in all higher subjects -- some people can think more abstractly with much more agility than others. If you're not a good abstract thinker, you have trouble with mathematics, whether it is on computer or by the teacher. It seems to me some people have natural limits.

Conceptions of Why Teachers Do not Use Computers for Instruction

Obed has been struggling to convince or encourage teachers to use technology in their instruction, but has not been successful. Finally, these are his personal experiences with teachers, and what he feels are the troubling issues include among other things lack of knowledge, which teachers hardly as their major setback. Obed said

My candid answer is, most teachers don't know computers well enough to enjoy working with computers. I also feel mathematics is taught in a rigid linear fashion, in which you start with lesson one and end in lesson fifty, and that mitigates against student progress. For instance, everybody learns via different means, some learn visually, and some learn abstractly. In English class, you see how some projects interest some students and other projects don't, whereas in mathematics, if you don't get it you don't get it. Why? because it is one shot thing -- a linear thing, you either hook in to it or you don't. My opinion is the teachers have learned their mathematics via one route, and they are not flexible enough to show alternate routes, nor do they spend enough time talking about the

concepts rather than numbers. You find a lot of students lost in equations and they don't even know the concepts behind the equations. It is the same in physics, there's not enough conceptualization.

Like most cognitive psychologists, Obed believes that the hood does not make the monk; the computer in itself is worthless if the lesson is not well designed to convey some understanding. The computer only does what the user wants it to do; if a teacher has some limitations in terms of knowledge, the computer will not augment it. In his comment, Obed said

If you bring in software that are fun and exciting into the class and demonstrate clearly to the students certain key concepts, the software will provide alternate form of teaching. Always bear in mind no teacher teaches what he/she doesn't know.

He stressed that a successful use of any technology goes beyond the subject-matter knowledge; it requires technical knowledge of the technology also. Obed noted that it could be embarrassing if at the middle of any lesson the instrument breaks down and the teacher cannot fix it; it kills the morale of the students, and fragments the lesson flow, especially if it happens more than once. He continued

If teachers are not comfortable with loading the discs, and if they don't have everything lined up and ready, for example, if students come in and say "Hey sir, mine doesn't work, or this doesn't work" and the teacher doesn't know how to fix that, then the embarrassment sets in and no teacher is ready to live through such stuff. So you've to be a special person to stretch beyond your natural limits before you can engage in that.

Another important point he mentioned was the teachers' academic background. He feels that borderline teachers hardly think abstractly. He noted

Secondly, don't forget there are lot of "C" teachers out there -- those who struggled with "Cs throughout their college years.

He has tried teachers in different settings with the use of computers and concluded that it is more of interest and knowledge than any other factor.

For example:

Our computer lab down the hall way also failed for English teachers because of couple of technical glitches that always demanded somebody's attention, and it was hard enough for an average teacher to fix it. People were scared of the technology or were not comfortable with it. Immediately the class starts, chaos begins and you have to rapid-fire answer everything and get the class going, therefore the technology should be smooth, easy, and clean, and still allow students to do very difficult things.

He argues that many reasons have been given for why computers are not constantly used. Some teachers attribute it to the unavailability of computers and lack of time.

Though these are cogent reasons, the most important question concerns what is done with computers. Obed argued:

Most cases we have brow-beating principals who want teachers give up their lunch hours, and you know teachers are already beaten up during the day. But the main question is what do we do with the computer labs? There's isn't a serious benefit to computing if it's just typing instead of writing. But if it is used for an in-depth editing and changing of sentences, switching of paragraphs, then there is benefit to having the computer.

Summary of Obed's Views

The following table summarizes Obed's views about educational goal, mathematics, teaching, learning, students, and potential role of technology in teaching and learning of mathematics.

Table 7: Summary of Obed's Views

Category	Teacher's Views/Perceptions
Educational goal	Understanding the connectedness of important mathematical concepts or ideas.

Mathematics	• Views mathematics as set of concepts and principles highly interconnected. • Teacher's in-depth knowledge of mathematics, or its narrow use is a function of the limits of the mathematics teacher.
Teaching and learning	• Rich repertoire of teaching methods. • Lot of group activities. • Assessment data to monitor students' progress and basis for making changes in classroom instruction. • Promotes teacher-teacher collaborative teaching, teacher-student and student-student interactions throughout the whole school. • Alternate teaching methods to reach the diverse group of students. • Treats students as responsible learners.

Students	• Students interests will increase if mathematics is fun and enjoyable. • Students' behavior is a reflection of the larger society. • Students are de-motivated because routine mathematics activities are boring. • Group students based on their choice and not forced into groups. • Genuine teachers' interests in students and students' learning promotes teacher-student interactions.
Potential role of computer technology in mathematics instruction	• Teachers should know how to teach first, before using technology for instruction. • Computers when constructively used, can extend the minds of students. • Computers when narrowly used makes mathematics a boring subject-matter. • Computers enable students to explore mathematical ideas beyond the traditional method. • Instructional software should be concepts oriented.

CHAPTER FIVE

FINDINGS ACROSS TEACHERS

In this chapter I examine the descriptive findings in Chapter Four in light of the conceptual framework and with regard to the research questions in Chapter One (p. 11). In organizing the findings of this study, the research questions provided the frames for discussions. These discussions are generally drawn from the analyses of teachers' conceptions described in more detail in Chapter Four. In order to understand how teachers' knowledge and beliefs about mathematics influence their use of computers in the classroom, teachers are grouped into two categories and displayed in a matrix as shown in Table 8 below. It is necessary to highlight that the matrix is a simplification of the complex phenomena of teachers' thought processes. It simplifies, as do all matrices, teachers' views and beliefs about their educational goal, mathematics, teaching and learning, students, and the potential role of educational technology in teaching mathematics into two broad categories. These categories are used in broad sense to show teachers general inclination -- eliminating much of the complexity of separating teachers' views.

The matrix table identifies the six teachers' general inclinations based on their educational goals and conceptions about mathematics, teaching and learning mathematics, students, and the potential role of educational technology in mathematics. Because differences among the teachers on the "conceptual - algorithmic", "student-centered - didactic", "responsible learner -

Table 8: Teachers' conceptions matrix

Teacher	Educational Goal	Mathematics		Teaching & learning		Student		Technology	
		Conceptual	Rules & Procedures	Student-centered	Didactic	Responsible	Receiver	Exploratory	Drill & Practice
Vesta	General skills and study skills	x		x		x		x	
Toniia	Emphasis on problem-solving skills	x		x		x		x	
Obed	Concepts and Ideas	x		x		x		x	
Bebe	Computational skills & life-skills		x	x		x	a		x
Kayce	Process development		x		x		x		x
Robinson	Computational skills		x		x		x		x

a = Bebe treats students either way (refer to Table 5)

receiver”, “exploratory - drill and practice” categories are striking, the teachers are arranged along this categories in the matrix table. While the ends of the mathematics continuum is clear with Robinson, Kayce and Bebe falling at the algorithmic end, Vesta, Tomia and Obed fall at the conceptual end. However, the differences among teachers on the conceptual end of the mathematics spectrum are not clear and distinct.

Excerpts of evidence that support placing a teacher in various categories are used in discussing the findings under appropriate research questions below. In discussing the research findings, there are instances where the frame of reference entails several large ‘chunks’ of descriptive evidence described in Chapter Four. This evidence will not be repeated but page numbers referring to Chapter Four will be given following a general description of these chunks. The descriptions are intended to highlight differences among various teachers while pointing out similarities across them.

Next, I will discuss the research questions starting with three sub questions (1A, 1B & 1C) followed by the main research question (1), and then the final question (2). It is important to remind the reader that question 1 has three sub questions that enable us explore extensively the main research question. While question 1A addresses what teachers know and believe about teaching and learning mathematics, question 1B addresses what teachers know and believe about computers and related technologies, and question 1C addresses how teachers use computers for mathematics instruction. Because all of the teachers except one, however, never used computers in their classes when observed, questions 1B and 1C will be discussed under a re-phrased research question 1B: what do teachers' know and believe about the potential role of computers in teaching and learning mathematics? This re-phrased

research question (1B) is intended to present teachers' views on what they know and believe about computers and the potential role of computers in mathematics instruction.

In order to discuss the main research question -- in what ways and to what extent do teachers' knowledge and beliefs about computers, and about teaching and learning mathematics influence the adoption of computers for instruction -- it is imperative to understand teachers' knowledge and beliefs about teaching and learning mathematics on the one hand, and their knowledge and beliefs about the use of computers and related technologies in mathematics instruction on the other. And since there are other factors beside teachers' knowledge and beliefs that influence teachers actions in the classroom, question 2 attempts to highlight such factors.

Research Question 1A: What Do Teachers Know and Believe about Teaching and Learning Mathematics?

Discussion of this question is presented in three sections: (a) teachers' conceptions about mathematics; (b) teachers' conceptions about teaching and learning mathematics; and (c) teachers' conceptions about students. Each section presents views across the teachers, as indicated in Table 8.

Teachers' Conceptions about Mathematics

The six teachers' conceptions about mathematics are classified roughly into two groups: those who view mathematics from a conceptual standpoint, and those who view mathematics as sets of rules, procedures and computational algorithms. The evidence supporting teachers' conceptions about mathematics were presented in Chapter 4; excerpts of that evidence will be used for discussions below. In the matrix at the beginning of this chapter, teachers were

placed into two groups according to their conceptions about mathematics: conceptual view or rules and procedures.

Vesta, Tomia, and Obed seem to view mathematics conceptually, whereas, Robinson, Kayce, and BB see mathematics as sets of rules and procedures to be approached step-by-step -- progressing from simple to more complex tasks. This classification was made based in part on teachers' responses to the following question: What kind of mathematics do you consider important for high school students? Although the question was followed with probes depending on each teacher's responses, the following excerpts summarize the responses of the teachers, starting with Vesta, Tomia, and Obed respectively:

Vesta

. . . . Applications of mathematics and problem-solving techniques are two areas of mathematics that should be continuously taught. Also I feel students should need to know the reasons why things are done the way they are done. If we as mathematics teachers take a little bit more effort in explaining these "whys", may be students might know that mathematics has more meaning than they have anticipated. . .

Tomia

I think the most important thing students should learn is problem-solving, because if they develop problem-solving skills, they can pretty much apply that overall.

Obed

Mathematics teachers should learn how to teach first before using computers. They should learn how to teach ideas, concepts, --- let the students be comfortable with the concepts and

On the other hand, Robinson, Kayce, and Bebe view mathematics as sets of rules and procedures. Although Robinson and Bebe did not state this view explicitly, I inferred the views by examining their entire responses. The following

responses by the teachers provide evidence for a view of mathematics as rules and procedures.

Kayce

I am interested in the process and not in the result. Process to me . . . is sequential steps, rules and procedures to follow.

Robinson

. . . if my teaching was concerned about equations. . . solving equations, . . . if I use the right method of teaching, and if I give you the right exercise on solving equations, my expectations are, you should walk out with the skill of solving these equations

Bebe

. . . In the first semester, say algebra 1, I spend half the semester to teach them how to solve equations because the skill level is not good and they are going to carry that the rest of their lives.

Summary of teachers' conceptions of mathematics. In summary, the six teachers have different views about mathematics that could be grouped into two broad categories: 1) conceptual view; and 2) set of rules and procedures. Vesta, Tomia, and Obed hold conceptual views about mathematics, whereas Robinson, Bebe, and Kayce view mathematics as set of rules and procedures. While teachers with conceptual views tend to empower students with general mathematical skills and problem solving skills, teachers who view mathematics as set of rules and procedures emphasize computational skills.

Teachers' Conceptions about Teaching and Learning Mathematics

Teachers in this study hold views about teaching and learning mathematics that differ in important ways from those underlining the visions of instruction presented by mathematics reform documents such as the NCTM

Standards (NCTM, 1989, 1991). Although their views differ among one another, one basic pattern of teaching -- from simple-to complex -- seems to be central for all of the teachers. This hierarchical structure of teaching permeated the majority of classrooms with low achieving students, due to the influence of teachers' perceptions about learners and learning. Their knowledge and beliefs about teaching and learning of mathematics have guided their practice over the years, and are consistent with the ways in which themselves were taught (Ball, 1988).

In this study, teachers' conceptions about teaching and learning mathematics generally fall into two broad categories: teachers whose teaching is student-centered and those who maintain the traditional method -- didactic method. Teachers who are student-centered engage in many activities that clarify understanding, much teacher-student interactions, and some student-student interaction. Also, they explore multiple resources and other active teaching aids that make mathematics fun and enjoyable.

While accepting that students are not performing at the expected level, teachers who are student-centered views attribute some of the problems to the structure of the mathematics curriculum and the delivery system. In an effort to accommodate these problems Vesta, Tomia, and Obed seem to approach teaching of mathematics from the student-centered view point, whereas, Robinson and Kayce who hold narrow views about mathematics argue that there is nothing wrong with the traditional method, rather, something is wrong with the way students learn. In contrast to a common practice, Bebe who holds narrow views about mathematics, designs his teaching of mathematics to be student-centered. However, his approach to teaching is dependent on the nature and type of students.

First, I present the views of teachers that are student-centered, followed by the views of teachers who see themselves as "traditionalists".

Vesta

Students need to have as many different approaches as possible to doing something. In mathematics, over the years, we've tended to isolate it to only one way of doing something, and I don't think that is right. Due to the rapid changing of the society, we cannot be set in one mode, you should be able to change or we should be able to deviate. I have realized that the old way is not going to work, lecture is not going to do it, so there must be another way of doing it.

In another statement Vesta said

Over the years, many students have developed a great dislike for mathematics and I try to change the attitude by introducing them to areas of mathematics that show the importance of knowing as much mathematics as possible and by showing them that they can succeed in mathematics. My wish for them is to have a love for mathematics that would show itself in their being "sponges" that could not get enough knowledge.

Tomia

I think a lot of things we do are logic, because we don't have a prescribed problem for them [students] to do, . . . for example, look at any story-problem, or an algebraic equation, . . . it is already set up, students only figure out the solution. My students have to figure out how to set up the problem, and then arrive at the answer. A lot of times, in constructions, I might put up a design on the board and say "create so and so". Then they have to figure out what is needed to create the design, . . . that makes them think logically. I do not set up the steps for them, which is the case in regular geometry proofs.

Although Tomia approaches teaching from a problem-solving perspective, she prefers teaching from simple through complex. She claims that it is one of the best ways of maintaining her students' interests.

I prefer teaching from simple to complex, because of the type of students we have in this building.

Obed

Obed believes that group work, non-routine problem situations, and multiple representations are powerful ways to explore mathematics and

construct mathematical knowledge. He feels that most mathematics teachers are not doing that because of their limited knowledge about the subject-matter.

I enjoy concepts and not twenty problems a night. I have good experience with graphs. Students who understand the concepts pretty well, after they're done with the formulas, do better with graphs. The important thing is to get the concept and lay-in the formula and fill down with. . . I also feel mathematics is taught in a rigid linear fashion, in which you start with lesson one and end in lesson fifty, and that mitigates against student progress.

Obed who is a strong advocate of teaching mathematical concepts says

Teachers should learn how to teach ideas, and concepts, -- let the students be comfortable with the concepts and then go over to the computer for the mathematics problems.

He believes that all learners will benefit from multiple alternate teaching styles since learning occurs through different learning media. For example, he says " some learn visually, while others learn abstractly".

On the other end of the spectrum, Robinson and Kayce hold traditional didactic views of teaching and learning of mathematics.

Bebe

Bebe is the only teacher who sees mathematics as sets of procedures but has student-centered approach to teaching. In his typical class, he facilitates the process by turning the class discourse to the students through probing and prompting:

I don't know if you'd call it "quizzing" or I just. . . I like to turn the questions around, so I'm asking the students. . . instead of them asking me. So, when it gets quiet and silent, I turn around and I'll start asking the questions out. And if they don't I turn more into a discussion.

Other than the way he runs his class, like Tomia, Bebe goes from simple tasks to complex tasks in his low ability class

It depends on the class I teach, . . . for example. all the students in this class failed algebra [the class he was teaching, when I interviewed, and not the class I observed]. . . In this situation I prefer teaching from simple to more complex. But in the other class [the one I observed -- the enriched class -- where every kid had an A+], I throw out the hard stuff

first, or I teach the whole and fill in the pieces later. In that class, I prefer teaching the hard stuff and most of them (the students) will probably decipher it, . . . and those who can't get at the first shot, will probably pick it up eventually. . . then we discuss the little tidbits later.

Robinson

Three premises seem central to Robinson's view of teaching and learning. First, he believes in a hierarchical structure for learning mathematics:

The facts remain, I don't see how any of these students can solve a problem/story-problem without knowing how to combine numbers on their own. There's no way students can go from number problems (without calculators) to word problems. So it seems to me there is a connection in the learning of mathematics and development, . . . the mental-development that goes from learning the numbers as facts, multiply and divide fraction, . . . before taking any step further.

Second, he believes memorization of mathematical facts and procedures is critical in learning mathematics:

From my experience in the area of teaching mathematics, if the students were not exposed to the rigors of doing simple level of working out simple fractions, numbers etc. mentally, he/she will not have the mental power to go beyond it.

Third, he has low expectations for students. He even anticipates the difficulties students would encounter in learning a topic yet to be treated. In his interviews, he claimed that efforts to present mathematics materials in ways that students could make sense of them as unimportant. Because he feels that students will never get it, he concludes that students are not prepared to learn, regardless of his efforts, as in the following excerpt:

The objective tomorrow will be teaching them Pythagorean theorem, and there will be a lot of difficulty in learning it, . . . in fact, you may have the impression that the target is 100% teaching, probably 90% learning, and 10% distraction based on other factors. . . but what is happening is 10% are learning and 90% are not learning. So it doesn't matter how much time you spend on it. . . . It doesn't matter how many assignments you give, . . . it doesn't matter how much yelling you do, how much calling you do to the parents. . . It doesn't matter what you do, they will not learn it. . . It is just that they are not into it, they feel that they have other important things to do.

From the excerpts above, it is evident that Robinson's view about teaching and learning mathematics stems from his conception about the nature and structure of mathematics. He believes that students can only learn mathematics after being mentally developed and exposed to the rigors of doing simple level work of fractions and numbers.

Kayce

Like Robinson, Kayce holds a didactic view to teaching and learning. He believes that cooperative learning or group work does not work:

. . . Well it seems that when I tried groups (and very little in my teaching career) . . . I lost control. Not that I have control, but you lose control. Right? . . . but I've never found it successful. I am not convinced that there's any learning going on in groups -- that's my bottom line.

Apart from his personal experience with group work, his beliefs about teaching and learning mathematics are re-affirmed by lack of positive evidence that supports effective learning occurs in a group setting. He recalls

. . . Secondly, I've not seen enough evidence to show learning takes place in a group as against the whole group. I try to adhere to the whole group, tied unto the fact that I'm not the primary source, the book is the primary source to get information from.

presumably, due to his convictions about how students learn, Kayce uses only the traditional method in teaching mathematics

This class is typical of the way I teach. I did the same thing four hours ago, I stood in front of the class, went over a worksheet with four different classes. . . So it's somewhat typical, I tried to run the control of the class from the front today, usually, if you get a uniform worksheet in front of the whole class, you get a little participation out of everybody.

students' lack of motivation and interest further frustrates his efforts

Yeah!. . . I tried to think of things that I can do that would stimulate their interests, but you get so frustrated with trying things new, you just. . . throw up your hands and say. . . We're going to do the 'normal' [traditional] thing. . . I get frustrated and say. . . why try?

Summary of teachers' conceptions of teaching and learning

mathematics. In sum, Vesta, Tomia, and Obed who hold conceptual views about mathematics including Bebe absorb some fault by treating their students as responsible learners. They present mathematics with rich repertoire of teaching methods in order to capture and maintain the interests of students. While teachers with conceptual views present mathematics in a variety of ways, Robinson and Kayce who see mathematics as set of rules and procedures present mathematics with narrow repertoire of teaching methods -- teaching as "telling" and learning as "receiving".

Teachers' Conceptions about Students

The teachers' views about students were also critical elements that shaped classroom organization and instruction. Although all the teachers agreed that students in their classrooms have low mathematics ability, are not motivated, lack interest in mathematics, and lack discipline, the teachers varied on what they saw as root causes and their expectations for students. Vesta, Tomia, and Obed believe that the traditional way of teaching mathematics is boring and unmotivating to students. They seem convinced that if mathematics is presented as an enjoyable subject-matter there is higher likelihood of students' participation and better result.

In contrast, Robinson and Kayce believe that students are not ready to learn. Robinson argues that "no matter what you do or say, these students will never get it". This perception must have influenced his beliefs about what type of mathematics the students need to know and how it should be taught. For example, Robinson and Kayce recounted their experiences with mathematics in their elementary school days -- how teachers and parents helped to shape their

mathematical knowledge and skills. Their knowledge, beliefs, and experiences have convinced them that students of today have failed to develop good study skills necessary for "doing" mathematics due to the collapse of the family structure on the one hand, and permissiveness of the society on the other. They compared and contrasted the past and present in terms of how in the past families provided learning environment and motivated students to develop their study skills but today, most families, especially in the cities, provide little opportunity or direction for students to develop personal study skills required for any meaningful academic work. Vesta, who finds herself in a similar situation as Robinson, reacts differently by saying, "most of my students have very weak algebra skills; unfortunately, I don't have the time to sit down with them as much as I would want to and fill-up the gaps". This suggests that if there is enough time, Vesta knows what to do to upgrade the skills of her students. Nonetheless, on the issue of students' behavior, Vesta is constrained to teach only in a normal routine classroom setting. She mentions

. . . in my second hour I discourage groups for obvious reasons. I don't think I'll use the computers in my second hour . . . um . . . I tend to be much more traditional, just because I get frustrated when I try new things with them. . . because behavior tends to be a little worse in a non-traditional setting.

Tomia feels dissatisfied with the way teachers teach mathematics. Her comment, "if students are not getting it, then teachers are doing the wrong thing," mirrors the concerns of reformers. She stresses that

The students are here to learn and not to cover 12 or 15 chapters of the book. If covering 12 means learning nothing, then we're doing the wrong thing and have failed. . . defeating our main purpose of education.

Like Vesta, Tomia thinks that it is the responsibility of teachers to understand the psychological demands of students and present materials in a way that will meet the needs of the students. She believes students are excited if materials are well presented when she mentions "you'll be surprised that even

the ones with low mathematics skills still struggle to get the right answer or to have some success with programs conceptually designed". In support of this positive view about students, Obed believes that students turn out to be responsible and motivated if teachers present mathematics in a more meaningful and interesting way to them.

Bebe in contrast, believes that since the low ability students have no need for higher mathematics, a life skill mathematics should be provided. By saying

I wish there are more life-skill mathematics taught. . . when it comes to such students who are not college bound, I think we should offer them more life skill mathematics

Bebe highlights the inflexible nature of the curriculum and believes alternate curriculum will better serve the needs of the low achieving students. Arguing on students' inability to succeed, Bebe thinks that students who are usually afraid to express their feelings in the normal classroom setting because of shame associated with failure, could express their views in smaller groups or when allowed to work on their own pace in a more positive learning environment.

In contrast to some of these views expressed by teachers who feel that some of the students' frustrations are caused by teachers, Robinson and Kayce think students and their parents or even the larger society are responsible for students' poor performance. For instance, in the following excerpts Kayce elaborates on what families are not doing.

I believe learning takes place at home. These students come to the class ill-prepared for school. But I do think the society has a role to play, but I think -- that goes right back to the home. I think learning takes place at home

While Robinson who comes from a background where only motivated kids have access to education consistently argues that students are being over pampered to the detriment of mathematics education, Kayce is simply frustrated with the nature and type of students -- the concomitants of a diverse

heterogeneous urban society with unequal social economic status. Kayce, with his strong religious background, seems to be alienated from the entire school system because he was strictly raised in a rural white community that attached importance to hard work and education. Both Robinson and Kayce, who claim to be of the "old school", insist that it is the student's sole responsibility to define and determine their future, while teachers provide relevant resources and necessary support. For instance, Robinson mentions ". . .it becomes up to the students who have interest to take advantage of the teacher to turn themselves around".

Another striking finding is teacher's expectation of students. Research has documented that there is a positive relationship between teachers' expectation and student outcomes (see Brophy, 1983; Brown & Baird, 1993; Good, 1987; Knupfer, 1993; Rosenthal & Jacobson, 1968) and teachers in this study hold some kind of expectations for their students. Teachers who hold views about mathematics believe that since their classrooms are filled with predominantly "low ability" students, engage only in activities or behaviors that maintain both the students' interests and their previously formed low expectations by assigning several worksheet problems on daily basis. But teachers who believe that students' success or failure is their primary responsibility tend to have a general value orientation that they can make a difference. With such optimism, these teachers' conceptually orient their interests toward using other instructional alternatives with their students.

Summary of teachers' conceptions of students. Teachers perceive students differently. While teachers who are student-centered views about mathematics believe that teachers have a strong role to play in the making of

good students, teachers with didactic (narrow) views seem to be frustrated with students' lack of motivation and interest to learn. Teachers who are student-centered argue that, in spite of the "baggage" students bring along, there is still room for the teachers to turn them around. In contrast, teachers with narrow views believe that students are responsible for being what they want to be.

In sum while conceptual teachers are seeing students through the lens of students, teachers with narrow views filter students through the lens of their existing views of what the mathematics should be.

Research Question 1B: What Do Teachers' Know and Believe about the Potential Role of Computers in Teaching and Learning Mathematics?

The use of computers in teaching and learning of mathematics has not significantly progressed despite its potential role in mathematics instruction. The seemingly slow progress in using computers for instruction, especially in mathematics, can be attributed in part to teachers' knowledge and skills to create and adapt materials into the existing curriculum, and their beliefs about how mathematics should be taught. Predictably, all the teachers participating in this study have used computers in one form or the other, such as, desk publishing, data storage and word processing. Most are constrained to these use, however, due to insufficient knowledge of and limited creative skills for using computers for meaningful mathematics instruction.

In discussing the teachers' views about the use of technology in mathematics teaching, evidence is drawn from teachers' interview excerpts. The teachers interviewed are experienced and seasoned teachers, (except for one teacher who is fairly new in the profession), and could be described as traditional teachers. With few exceptions, most of the teachers have some kind

of knowledge and virtually some type of skills in using computers for instruction. No doubt, their knowledge about computers and the use of computers vary among the teachers. However, two general patterns seem to emerge from the findings: (a) teachers who have used computers for instruction and tend to use computers as a tool that extends the minds of the students -- exploratory; and (b), teachers who have not used computers for instruction and, to the extent that they consider using computers, see them as tools for reinforcing facts and computational skills -- drill and practice.

The matrix at the beginning of this chapter classifies teachers' views into these two broad groups: (a) exploratory, and (b) drill and practice, as these were the predominant approaches teachers considered. Discussions on the above question will therefore focus on teachers' views from these two broad categories.

Despite these two broad views, findings indicate that although teachers have some knowledge and skills about computers, that knowledge is not "sufficient" to fully explore the flexibilities and potentials of computers for mathematics instruction. Therefore, teachers generally are not very confident and comfortable with the use of computers and other computer technologies in their classrooms. Most of the teachers anxieties are not (as is often assumed) based primarily on the unavailability of the hardware but on their own inability to use computers extensively for good educational purposes in their classrooms.

Teachers' concerns also are linked to their own doubts about the extent to which their students will benefit from their limited or insufficient knowledge about computers and useful mathematical software necessary for high school mathematics. Findings indicate that the inefficient use of computers could possibly lie with teachers' views about teaching and learning of mathematics,

and in part, the structure and design of the curriculum. This assumption may be valid because the curriculum and pedagogy often determine whether or not an innovation is beneficial to the students and the classroom discourse (Heywood and Norman, 1988), but will be discussed in detail in the next question.

In extracting from the excerpts of the interviews and putting them in a logical sequence, I provide an understanding about the flow of thought of some of the teachers, starting with teachers who hold exploratory views about the potential role of computers. The following excerpts briefly describe the teachers' conceptions about the role of technology in mathematics instruction. First, I present what they believe about the technology itself, and then how they use it or intend to use it, starting with teachers who hold exploratory views about computers.

Vesta

Vesta sees computers as the educational tool of the future and believes that computers will play a critical role in classroom instruction.

Everything is computerized, there's no way computers will disappear in the near future. It may take a new form and be easier to deal with. . . . I also predict that it will soon take over education, either at the college level, but it will definitely take some of the old ones to be gone.

Vesta also believes that computers offer alternate and multiple approaches to teaching and learning mathematics when she says

Students need to have as many different approaches as possible to doing something. In mathematics, over the years, we've tended to isolate it to only one way of doing something, and I don't think that is right have realized that the old way is not going to work, lecture is not going to do it, so there must be another way of doing it.

In spite of her frustration with students' low mathematics skills, Vesta still has the desire to use computers more often in her classroom in order to make mathematics enjoyable to her students. She comments

If I think of any of us, I'm probably the only one that uses technology for instruction and. . . I think I'm the only one that has the LCD panel. But my biggest challenge is to know how to use the software that I have, and remembering to use it on a regular basis and using it to its best advantage

Vesta has interest in using computers for instruction, but was constrained by her inability to figure out optimal ways of handling the tool. Interestingly, she openly admits that enthusiasm alone is not enough to support computer use in mathematics instruction; it demands time and talent. Her emphasis on time and talent is striking and critical to the type of decisions she makes in the classroom.

I'm pretty familiar with what the machine can do, but shaky when it comes to creating my own ideas. Managing everything that goes along with it is not an easy task, because it changes you, it changes your approach to teaching, so you've to be prepared since it demands both time and talent.

In concluding Vesta's views, it is clear that she has made striking efforts in departing from the traditional method of teaching by trying to use computers differently. Her approach to this new way of teaching stems from her educational goal and beliefs about teaching and learning mathematics. Some of her constraints in fully adopting this technology in her instruction hinge on her limited knowledge about the optimal use of computers for mathematics instruction and skills to create customized materials to serve the needs of her students.

Tomia

Like Vesta, Tomia is a strong advocate of the use of educational technology, especially computers for classroom instruction, probably due to her knowledge and background in computing. She says,

I decided to use the computer because the traditional method --lecture style, was not working, so I thought of doing something different. I have always liked computers, and I have taught computer classes for so many years. When you start using computers for mathematics classes, you will experience that there is much to mathematics and it is fun doing mathematics.

Since Tomia educational goal is problem-solving, she uses computers in ways that are consistent with her views. To her, computers in the classroom change how mathematics is being taught and engage the attention of both students and teachers alike. She recalls that

It was a lot more work than the normal class classroom. In the traditional setting it's easy . . . once you get the students working you can just sit down . . . or go to your desk and do whatever you want to do. In the lab setting, it was hard to do so because there is no time to sit back and relax . . . you'll be constantly moving around . . . but that was great for me . . . so it worked out good, but like I said it is a lot of function anyway.

In sum, Tomia prefers the use of computers to traditional teaching methods. She argues that students learn more with computers than the traditional way, because computers tend to hold their interests longer and offers some learning capabilities that are congruent to their learning styles outside the classroom. For example, TV games like *Nintendo*, *Sega*, etc.

Obed

Obed has been particularly creative in integrating technology in the existing curriculum. He seems to be quite knowledgeable in computing and has been using technology for almost a decade. About his goals for computer use, he says,

I think the ultimate use of the computer as an extension of the mind is for the student to invent on his own new knowledge and use the computer as a tool to help him/her think or even as a note-taker.

Obed contends that most teachers are constrained in using computers to teach because of their limited knowledge about computers. He says, "My candid answer is, most teachers don't know computers well enough to enjoy working with computers", and he further explains that "computer is only a tool for instruction and does not augment teachers' limited knowledge."

In sum, Obed thinks that computers if properly used, are excellent teaching tools especially in mathematics. To him, any teacher who is not using computers for instruction, either lacks the knowledge and skills about computers, or lacks an in-depth knowledge about the subject-matter.

Bebe

Unlike Obed, Bebe confesses that he is not knowledgeable about the use of computers for mathematics instruction:

I think majority of the teachers (including me) probably are not computer literate per se. I was on the borderline when computers started getting into the college. I got a little bit of computers while in college, but not to the extent of being comfortable with it, because of my poor knowledge in this field. Therefore I will not feel comfortable teaching it with the knowledge I have now.

Because of his educational goal, Bebe intends to use computers in ways that are congruent to his beliefs. He states

I would like to see some type of program set up as a supplementary tool for homework problems that we are doing. So if a kid is struggling with a homework assignment in a certain area, you could pull up the computer to produce ten practice problems right away and the kid could sit down during lunch or after school to do them

The above excerpts also suggest that Bebe sees computers as useful tools for individualized instruction. According to him, individualized instruction will benefit every student, especially students who are "shy" in a regular classroom setting. He believes that one-to-one interaction between the student and the computer will provide the type of environment such shy students need.

In sum, Bebe claims that he lacks the courage and confidence for using computers for instruction because of his limited knowledge about computers. In spite of his deficiencies, Bebe has not seen computers as central tool for mathematics instruction, rather, as a supplementary tool for homework assignment and individualized instruction (see his excerpts above). Therefore, he intends to use computers in a narrow way that is parallel to his knowledge

about computers which seems in conflict with his views about teaching and learning mathematics.

In contrast to these efforts, Robinson's and Kayce's concerns focused on the moral decadence in the society, breakdown in school system and students inability to be active listener.

Kayce

Kayce, has some knowledge about computers, and has taught computer classes in the past. He suggests that computers can only be used as a tool for drill and practice in mathematics instruction. It is not clear why he has not used computers in his classrooms, but it is clear that he is not sure of how his students would benefit from them. He says

Computer is important for various reasons, but in terms of using it for mathematics instruction I think something has to be done. Right now, it will only be used for drill and practice, and that is what most of our students need. . . I have very little idea of how students would learn with computer, other than remedial work.

Kayce draws more from his perception of learning and his low expectation of students based especially on what he described as “wild” behavior. First, he commented that learning does not take place in cooperative learning or group participation, therefore, computers are only effective in remedial activities and individualized instruction.

Second, Kayce feels that students are destructive and less motivated to study, using computers differently will not help students learn mathematics. To him, computers could be used to keep track of students activities, without necessarily slowing down the pace of bright students. His rationale for paced instruction follows one line of thought that dominated his early childhood education. According to him, learning or studying takes place at home or outside the classroom. The classroom is meant to provide relevant information through the teacher telling and the students listening.

Ordinarily, Kayce who one would expect to become a more powerful computer user (given his teaching computer skills), was instead restricted to drill-and-practice that lends support to his views about teaching and learning mathematics. The question that comes to mind is, why did Kayce not transfer his programming skills to "tools applications"? A hypothetical line of thought is that computer programming is more rigid, teacher-centered, and consistent with step-by-step learning environment. This teacher-control type of learning serves or suits Kayce's educational goal and also congruent to his beliefs. Whereas, using computers as a tool application is student-centered --encouraging students to explore new ideas on their own -- removes control from the teachers and conflicts with his existing beliefs about how teaching and learning mathematics.

Based on Kayce's conceptions, his classroom seems to represent a typical mathematics class, where the teacher presents the "process" of solving mathematical problems with the assumption that students will learn it. To be consistent with this narrow view of teaching and learning, Kayce believes that computers should be used for individualized instruction and drill-and-practice activities.

Robinson

Robinson argues that while computers and calculators are necessary tools for higher mathematics, they are not necessary and are not required at high school mathematics. He further claims that

Because I have done computer mathematics . . . and I've seen the necessity for it at high-level mathematics. . . But at the level of the high school, whatever we do with computer technologies will just be computer game.

Robinson argues that "learning of mathematics is doing it", and he believes that for students to be active learners they must have the ability to memorize and retain certain mathematical facts. According to his line of argument, the calculator and computers render students mathematically inept because computers and calculators perform those fundamental mathematical functions that should be memorized by students. From this view point, Robinson thinks that computers and calculators should be used for reinforcement through drill-and-practice.

Because of his knowledge about computers and his convictions about teaching and learning mathematics, Robinson believes that computers can effectively be used only when it is integrated into the mathematics curriculum. A striking fact is, even if computers are integrated into the curriculum, Robinson stresses that he would restrict the use of computers for "remedial and administrative purposes", given the low level high school mathematics.

Robinson who rejects the use of computers in mathematics instruction is a good example of typical educational system that is suspicious of changes that inject new patterns of behavior and threaten traditional beliefs. He seems to be aware that the introduction of computers requires modification both in attitude and way of teaching but argues that the change is unnecessary. In addition to his conceptions about the negative effect of computers, the realization of the type of students he is working with, may have induced more fears in him. For instance, Robinson regards the use of computers as a distraction in the classroom and does not believe computers have yet had positive effects on mathematics learners at the high school level (Hall & Rhodes, 1986). Therefore, his "resistance to change naturally followed" (Knupfer, 1993). In sum, Robinson lacks knowledge and skills about using computers in mathematics instruction.

He intends to use computers for drill-and-practice whenever he has the opportunity.

Summary of Responses to Question 1B

Inherent in the emphasis on having sufficient knowledge about computers is an image of the teacher as a professional who knows what is required to make decisions about what to teach and what tools to use in teaching. To a certain extent, the teachers' differing knowledge about computers reflected their different views about the potential role of computers for instruction. Vesta, Tomia, and Obed, who have some knowledge about computers, view computers as a powerful tool for exploration and has the potentials of improving mathematics instruction. They believe that computers have the potential of altering the way mathematics is taught in classrooms. For example, Vesta commented that "by having the technology available, I think our curriculum can expand to areas that will allow both teachers and students not to be stagnant [in mathematics]."

In contrast, Robinson and Bebe who have virtually no knowledge about computers do not see computers as a central tool for mathematics instruction and therefore intend to use computers for drill-and-practice and other remedial activities. Unsurprisingly, Kayce who is quite knowledgeable about computers, but views teaching and learning of mathematics as a set of rules and procedures, intends to use computers narrowly. While Robinson believes that computers are not required for high school mathematics and will not use it as instructional tool in his classroom, Bebe and Kayce see the need for computers in high school mathematics, but to be used primarily for drill-and-practice.

Vesta, Tomia, and Obed, who want to use computers in exploring mathematics, tend to share one basic assumption. For instance, Tomia's comments about the importance of computers in mathematics instruction also suggests that she presupposed that the traditional method is no longer serving the wide range of students found in urban schools. Even in her discussions about potential role of computers in the classroom, she talked about her convictions that computers are likely to re-vitalize the teaching of mathematics. In support of Tomia's view, Vesta believes that computers are tools for the future, especially in mathematics and Obed feels that computers will offer better and multiple teaching approaches to mathematics teachers if properly used. For Obed, the teacher should have an in-depth knowledge of the subject-matter and the educational tool he or she intends to use. In contrast to these views about the potential role of computers, Robinson, Bebe, and Kayce believe that computers should be used to reinforce what the teacher has presented.

In the above examples, the vital role of teachers' knowledge and beliefs about the use of computers in mathematics instruction is important. Such instances highlight the centrality of a rich and explicit knowledge of both the subject matter and the tool for instruction. Reflecting on some of the discussions and observations, there is no clear distinction on what influence is stronger: whether what teachers' know about the subject-matter or what they believe about what students need to know and how they should know it. But it was apparent that both what they know and believe influence their classroom practice.

The next question will examine the relationships between what teachers know about the subject matter, what they believe students should know, and

how they should know it and the potential role of computers in mathematics instruction.

Research Question 1: In what ways and to what extent do teachers' knowledge and beliefs about computers, and about teaching and learning of mathematics influence the adoption of computers for instruction?

Important Emerging Findings

Much of what was learned in investigating teachers' knowledge and beliefs about the role of technology in mathematics instruction lends support to some of the barriers already mentioned in Chapter 2 which reviewed research on the importance of computers in education and teachers' knowledge and beliefs about educational technology. For example, past studies have revealed that most teachers currently in the system were not raised in the electronic era, and most of them have complained about cost and unavailability of hardware/software. Rather than repeat the same results, attention will be given to a few of the more significant findings that address the main research question. In this study there is a significant finding:

Teachers' knowledge and beliefs about mathematics, and about teaching and learning of mathematics influence the way computers are used or not used in the classroom.

This claim is substantiated by the following findings:

1. Teachers who view mathematics conceptually tend to use computers to extend the minds and knowledge of students,

whereas those who view mathematics as a set of rules and procedures, tend to use it for reinforcement, drill-and-practice, and remedial activities.

2. Teachers who view mathematics conceptually seem to be more open to new ideas, flexible, and comfortable with computers -- making efforts in integrating computers into the existing curriculum, -- whereas teachers who view mathematics as a set of rules and procedures rely heavily on textbooks and are not making efforts toward using computers for instruction. Due to their over reliance on textbooks, these teachers seem to be threatened that computers will remove them from the textbooks and possibly lead them to "unfamiliar territory."

In discussing this main research question, evidences will heavily be drawn from the responses to questions 1A and 1B above.

Teachers who view mathematics conceptually view the use of technology as a tool that will extend students' knowledge and articulate mathematical concepts more clearly for their understanding. In contrast, teachers who view mathematics as set of rules and procedures -- as a step-by-step procedural subject -- report that technology should only be used for purposes that emphasize the important steps and recognize the right or wrong answers through either drill-and-practice or remedial activities.

Irrespective of the teacher's perception, all the teachers highlighted that students' learning is central to their educational goal. Their conceptions about mathematics and interpretations of what student learning should be, influence their teaching strategies. For instance, Robinson who sees high school

mathematics as watered-down mathematics, and who does not see the necessity for computers and calculators, possibly holds the assumption that students should easily memorize the basic computational facts. In planning his teaching strategies, Robinson relies heavily on textbooks that are recommended for his class and compatible with his beliefs about mathematics -- algorithmic computations. And Kayce who has some knowledge of computer programming but believes in teaching as "telling" and learning as "following instructions" does not see the need in using computers differently other than for drill-and-practice and remedial activities.

Both Robinson and Kayce implicitly regard "active" students as those who pay attention in class, attend to their class assignments, answer to questions or who care to put in extra hours during lunch breaks or after classes. They do not believe that alternate ways of teaching are effective neither do they consider computers as tool that could create a learning environment that could motivate students or extend their knowledge.

In contrast, the other teachers who view mathematics conceptually believe that students will become motivated to learn mathematics if mathematics becomes more interesting and meaningful. Based on this assumption, they tend to create alternate learning environment to achieve this goal. Their interpretation of student learning is in engaging students through active participation such as group learning, cooperative learning, and individualized learning. This group of teachers believe this effort can be augmented through the use of technology like computers.

Before this study, it was an inherent assumption that teachers with long teaching experience may lack the motivation to adopt a tool that will make them deviate from their "mastered" routine only to create more work and draw on their

resourcefulness. Expanding on this assumption of a potential relationship between age and resistance, I discovered instead that resistance hinges more on knowledge and beliefs. Interestingly, in this study teachers with longer years have more knowledge and experience in computing and are more interested in the use of computers than the younger ones. For example, Robinson (10 years) and Bebe (5 years) who have less teaching experiences have neither used computers for instruction nor taught any computer classes. In contrast, Vesta (17 years), Tomia (18 years), Kayce (28 years) and Obed (23 years) either use computers for instruction or must have taught computer classes. There is no doubt that a technology such as computer that will confront teachers' knowledge, and stretch their skills and practice will hardly be used in the classroom of teachers who are not so sure about the potentials of the technology.

Ultimately, teachers who hold conceptual views about mathematics and whose views are congruent with the visions of the mathematics reformers show positive attitude toward the use of computers for instruction, adapt different teaching techniques to demystify mathematics as a "myth" and promote mathematics as a fun and enjoyable subject. In contrast, teachers who hold a view of mathematics as sets of rules and procedures seem to hold narrow and negative views about the role of technology in teaching and learning of mathematics.

Teachers who hold this general or narrow view about mathematics have some difficulties integrating computers in instruction, which is consistent with other studies' findings that concluded that teachers' perception of mathematics shape the way they teach (Ball, 1988; Putnam et al., 1992). In this situation influence the way technology is used or not used in the classroom. It is evident

that instructional computing challenges traditional instruction [see Chapter Two], possibly transferring the focus from the individual teachers to a multitude of instructional sources such as computer programs, databases, and student discoveries. "This challenge places unusual stresses on the classroom teacher and amplifies the importance of the teachers' attitude toward computers. It is the teacher who lives with the innovation and it is ultimately the teacher who will accept or reject, implement successfully or fail to implement technology in the classroom" (Knupfer, 1993, p.172).

To overcome teachers' initial obstacles, Vesta, Tomia, and Obed believe, it requires teachers' interests, efforts, and creative ideas. Vesta emphasized that creative ideas are paramount and should be demonstrated by a resource person or an expert to cue the teachers. The three teachers strongly believe that computers have come to stay and will be the technology of the future and those teachers who fall behind now will soon face the problem of declining students' interest as the novelty of computing -- drill-and-practice wears thin.

In sum, teachers' knowledge and beliefs about mathematics, teaching and learning mathematics and instructional technology influence the use of such technology in the classroom. Teachers who believe that if mathematics is presented as a fun and interesting subject-matter students will learn more are more likely to create a learning environment that meets their goal. In contrast, teachers who view mathematics as set of rules and procedures seem to encourage the traditional classroom and are more reluctant to try alternate teaching methods.

However, much of these latter teachers' self-definition revolves around their views about mathematics and the role of technology in instruction, and in part, the anxiety generated by their unfamiliarity and being "not too sure" with

the new machine vis-a-vis mathematical software. Another troubling reason for their reluctance to use technology could be the imposition of teaching students who show neither interest nor aptitude for on-going classroom intellectual development, reinforcing teachers' reluctance to use a tool that demands students' creativity.

The fear of being embarrassed was considered before the research as a major de-motivating factor in the acquisition of the skills needed to use computers for mathematics instruction (Honey, & Moeller, 1990; Kerr, 1991; Sheingold & Hadley, 1990), but strikingly, the teachers studied seem not to bother about being embarrassed in the presence of their students. Rather, most of them are more concerned with the "unproductivity" of the whole exercise and waste of their time, since [according to them] nothing meaningful will be achieved in such a futile activity.

General Reflections on Main Research Question

The proponents of instructional computing have stressed the issues associated with the change process, implementation and equity, but have neglected the opinions expressed by the teachers and their role in the change process. Similarly, the administrators of school B neglected the efforts, concerns and interests of teachers by selling the mathematics computer laboratory. Yet, these teachers are part of the "equation" and essential to the successful implementation of computers in the classroom (Cuban, 1986; Knupfer, 1993). It is the teacher who must adopt and adapt computers to curriculum goals and classroom needs (Cuban, 1986; Fullan, 1982), and such educational change enterprise depends on what they do and think (Sarason, 1982, 1990).

The current reform documents like the NCTM *Curriculum and Evaluation Standards* are asking teachers to view mathematics in new ways -- in ways they never experienced as learners or as teachers. This means changing teachers' beliefs about mathematics and their attitudes toward creating a new classroom structure that supports active learning. Since the teachers' roles are central to any change, and the teacher lives and works in a classroom with its own "built-in imperatives and social culture" (Knupfer, 1993), the teachers' real working conditions should then be taken into consideration.

Teaching mathematics with computers demands a change in the structure of the daily lessons. The traditional teachers who use computers in their classrooms are beginning to realize that once they become secure with their ability to use the technology, the very structure of their teaching changes. They also acknowledge that to be successful at this new method of teaching, they are willing to relinquish their authority over learning, to give students the opportunity of controlling their learning. This willingness of teachers to change their current practice must tip the balance in favor of the anticipated changes and will also provide evidence and support necessary to prompt the interests of non-users.

Research Question 2: What other factors do teachers report affect the adoption of computers and related technologies for mathematics instruction?

In this section I present other factors teachers reported that influence the use or non use of computers for mathematics instruction. Most of what the teachers reported is consistent with what past studies have indicated according to literature reviewed in Chapter Two. To be clear and concise, I will highlight some of the pertinent salient points across the teachers and also group them

under the following headings: 1) accessibility; 2) classroom arrangement and scheduling; 3) training; 4) time; 5) curriculum; 6) discretion versus direction; 7) context and other intangible issues. In discussing these factors, I will reference only evidence of one or two teachers that support the argument being discussed.

Accessibility

The practical considerations of students having access to a sufficient number of computers in the classroom and to an equipped computer lab, together with quality instructional software were central to almost all the teachers. Unfortunately, the two schools A and B that participated in this study, have no computers in the classrooms for students since school B sold the only mathematics computer lab. Rather, each school has a computer lab for computer classes accessible to all high school students and not specifically for mathematics classes. Kayce and Bebe have a computer that is remotely placed at the corner of the classroom and never used for instruction, Vesta has her two computers which she uses for instruction and are conspicuously displayed at the front of the class, Tomia and Obed have access to the computer lab which is next to their classrooms. The lack of availability of computers and related technologies sends a strong message to the teachers that it is not time for instructional computing. Although the computers are not available, however, all the teachers indicated in their interviews and discussions that they would like each student to have access to a computer. For example, Vesta says "by having the technology available, I think our curriculum can expand", and Bebe describes a perfect situation as "every student to have a computer"

Classroom Arrangement and Scheduling.

Another critical factor is the physical appearance of the classrooms (without computers) and the message it communicates to the teachers and students. Since the physical environment has a profound impact on human behavior and projects a nonverbal message to the teachers, again, most of them still feel the school is not prepared or it is not time to use computers for instruction. According to Kayce, the physical environment and the structure of the high school classes -- students moving in and out every hour -- is already a barrier to the use of computers and group learning. Kayce emphasizes that

... in high school, we have five classes with different sizes, bursting in and out . . . here's a physical problem and too much turmoil, but it may work with adults. As opposed to elementary school teacher who has one class all day --- can group the students in anyway he/she wants.

Training

Much has been written about in-service training and the necessary training teachers need to become proficient computer users (Barker, 1986; Sheingold et al., 1981). All the teachers acknowledged the importance of training, but tend to disagree on how the training should be offered. For instance, Bebe calls for going back to school, Kayce advocates university-school collaboration, Tomia wants a district wide on-the-job training that results in teachers creating their own materials, while Vesta calls for a trainer who will if possible practically demonstrate how to integrate technology into the existing curriculum -- using parts of the lessons as examples. It is clear that no matter the nature and type of training, teaching teachers how to use technology in the classroom is central for effective use of instructional technology in mathematics instruction. According to an elementary school teacher, "all teacher in-service

training days should be devoted to technology, teacher evaluation should include regularly uses of instructional technology", and finally the school administrators should model the appropriate use of technology and should be proficient too.

Another striking point raised by Vesta and Tomia is teachers' interest. Tomia has some reservations on the issue of training as she indicated that "some of the teachers are familiar with the computers, but never did a whole lot when we had the mathematics lab". To her, teachers' interests seem more important than the training, although she has a contrary view when she says that district wide training will probably capture the interest of 50% of teachers. I believe, however, that there are important points of intersection in Tomia's seemingly inconsistent views on teachers' training and interests. A deeper look on the issue of training and interest rests on the assumption that what teachers know and believe influence what they do. Conversely what they are exposed to (either through training or practice) also influence what they know and possibly change their beliefs. The link is the recognition of either teachers' interest or training or combination of both is central to the successful use of instructional technology in the classroom.

Time

Time is a strong theme that was constantly used by all the teachers. Teachers strongly feel that they have been over-stretched in term of their time. As Obed rightly puts it, "most cases we have brow-beating principals who want teachers give up their lunch hours, and you know teachers are already beaten up during the day". Also studies (Sheingold & Hadley, 1990; Zammit, 1992) have documented in order for teachers to become proficient computer users a

substantial amount of teachers' time is required. In my discussions with Vesta and Tomia, it was evident that teachers need not only substantial amount of time to acquire the knowledge and skills, but also need some reasonable amount of time to prepare the materials for instruction -- time for reviewing the instructional software and sequencing their lesson plans and strategies.

However, Vesta and Tomia argue that teachers must not wait to be proficient before using computers for instruction, because there may never be time for that. Their line of argument is based on the assumption that "you don't have to be a master "mechanic" in order to drive a car". They believe that knowledge could be acquired through trial and error, and good experiences are developed through learning from one's mistake and with time. Again, I believe Tomia and Vesta are looking at the minimal time any interested teacher needs to get started given the relevance of their working environment in terms of the district's bureaucracy and politics in providing teachers with time and the necessary resources on the one hand, and the rapid changes of instructional software on the other.

In sum, learning to teach in a new way, according to one teacher is even more difficult than learning to teach for the first time. Beyond the wish to maintain professionalism, it takes time, it requires much practice, tolerance for mistakes, and readjusting to a new way of marking progress along the way. Teachers should be given adequate time to reflect on their teachings and time to try new teaching methods.

Curriculum

Teachers who hold narrow views about mathematics seem to follow too rigidly a curriculum that emphasizes strong computational skills and evaluates

students mathematical ability on "right or wrong" answers. Bebe's confession about the incompatibility of computers and the existing curriculum speaks for most of the teachers, especially Robinson. The remarkable difference between teachers who share conceptual views about mathematics and those who view mathematics as bunch of computations lies on how they approach the curriculum. While Vesta, Tomia and Obed tend to modify the curriculum to meet their educational goal and their perceived needs of the students, Bebe believes that unless the curriculum is changed or modified, computers can not be used effectively in mathematics classroom. In as much as this view is consistent with his views about mathematics, it is equally consistent with the visions of proponents of school mathematics reform. However, the unanswered question is, if the curriculum is modified, will Bebe filter the information provided through the lenses of his current knowledge and beliefs about mathematics? (Ball, 1988; NRC, 1989, Paulos, 1988; Putnam et al., 1992).

Irrespective of teachers' views, all the teachers want a new curriculum that accommodates instructional technology, offers different mathematical contents that serve the needs of the students and multiple teaching alternatives. Curriculum dictates what to teach and to what extent and the impact on classroom discourse cannot be over emphasized.

Discretion Versus Direction

Another unanticipated finding concerns direction versus discretion. According to all the teachers there is no clear objective described at the administration level for teachers to follow. Because there is no clear cut direction from the district or administrators, Robinson and Bebe raised questions like: What are the goals and the essentials of instructional

computing? What are the practical implications of instructional computing in mathematics instruction? Unfortunately, because nobody seems to be answering such questions, teachers are further removed from the use of computers in the classroom. It is clear that since teachers are professionals who make judgments, within specific contexts, they are constantly challenged in working within the repertoire of possibilities, making decisions in the context of competing concerns and demands (Darling-Hammond & Wise, 1985). Shulman (1983) also noted that initiatives for change "must be designed as a shell within which the kernel of professional judgment and decision making can function comfortably" (p.501).

In my discussions with the teachers, some mentioned that if instructional computing is a worthwhile teaching and learning activity the authority or policy makers could have provided them with working guidance and guidelines to facilitate such a change. This argument is legitimate and Boyer (1990), though not a mathematician, argued that far more attention needed to be given to pedagogy. According to Boyer, "it is not enough to suggest active learning and cooperative practices without greater clarity about how teachers might move constructively in those directions".

In another account, Gross et al. (1971) research on curricular innovation suggested that 'lack of clarity' was a major setback and cause of failure in implementing new ideas. In most cases, teachers who are always prepared to support the rhetoric of what was being advocated often found themselves unclear about precisely what was meant to happen in practice. Similarly, the introduction of computers into schools shows the same lack of clarity and educational purpose, and teachers have highlighted the magnitude and difficulty of the necessary changes in pedagogy. Gross noted that this lack of

integration with the regular curriculum is also reminiscent of the fate of many 1960s experiments in educational technology.

Context and Other Intangible Issues

It will be out of place to remove teachers completely from the context within which they do their job. During my interactions with the teachers it was commonplace that teachers drew on what they knew about the school community, the school district, and the school administrators. For example, all the teachers know that the students are diverse and from mixed socio-economic status, with the majority of students coming from low SES. Teachers' knowledge about the community also influences the way their classes are conducted. According to Tomia (in school B) neither parents, nor the school authorities have ever during her 15 years of teaching asked what is the curriculum and how are teachers following the curriculum. Therefore, common sense informs us of what happens when teachers are not bothered with what they teach and how they teach it. This context-specific view of human behavior contributes much to our understanding of the poor performance of many low-income and linguistic minority students (Cazden, 1986). Cazden suggested the need for teachers to vary instructional circumstances in order to take full advantage of students' unrecognized resources. In contrast, Robinson and Bebe (in school A) complained about how teachers are strictly required to follow the curriculum.

Since it is extremely difficult to elicit teachers' thought processes completely, there are countless factors that guide teachers' actions in the classroom. Some of these intangible factors are inherent or acquired, but significantly influence teachers' selection of teaching and learning activities. For example, according to Knupfer (1993)

Teachers' attitudes shape the daily classroom routine and the specific opportunities for access to particular learning activities. These attitudes can influence and uphold teaching behavior that is either more or less fair and reasonable. For example, qualitative, subtle inequity involves intangible attitudes and institutional biases that presumably pose a greater long-term threat to equal access and use of computers than those more tangible factors (p.168).

It is beyond the scope of this study to examine in fine detail what intangible factors that are often neglected but critical in shaping the classroom routine. Further study should examine these intangible factors such as "not nominated to sit in the innovation committee" or "Why was Ms. J given the IBM 486 model and me the 386", "why was this low ability students assigned to my class?" Such seemingly insignificant problems if left unchecked, are likely to generate ugly feelings amongst teachers.

So far, this section has considered how the context and the intangible factors might affect the way teachers view and use computers. From the above discussion it is difficult to identify what effect causes what because they are intertwined, complex and often operate in combination. But it is evident that no matter the factor that influences teachers' decision it will definitely impact the use of computers in the classroom. While the context is analogous to the shell, the intangibles are the parts and pieces that keep the teachers going, and everyone is important. In sum, the context and the intangible factors such as teachers' social preconceptions and emotions can have tremendous impact on instructional computing.

CHAPTER SIX

SUMMARY, IMPLICATIONS, AND CONCLUSIONS

This study investigated teachers' knowledge and beliefs about the role of computer technology in mathematics instruction in high schools. The main motivation for the study was to join efforts to improve the quality of teaching and learning of mathematics because of increasing concerns about students' poor performance in mathematics (Dossey et al., 1988). The study's focus was on understanding why computers and computer technologies are not used more frequently for mathematics instruction in high schools, despite its flexibilities and potentials in education and the fact that it has been more than a decade since computers were introduced in schools. Studies in cognition have revealed that some of the criticisms about educational technology research, especially about computers, have its central focus on technical efficiency, students' interaction with computers and educational outcomes. There is little information available to answer questions such as: How can the computers be used in existing subjects? What kind of knowledge do teachers need to have to integrate computers into the existing subject? What are the effects of computers on teachers' beliefs, instructional strategies, and classroom organization? (Plomp & Pelgrum, 1993). This study tried to unpack some of the dilemmas

mathematics teachers face in making decisions about the use of computer technologies in mathematics instruction.

The following questions served the focus of the inquiry

1. In what ways and to what extent do teachers' knowledge and beliefs about computers, and about teaching and learning mathematics influence the adoption of computers for instruction -- the relationship between A and B as shown in Figure 1?
 - 1A. What do teachers know and believe about teaching and learning mathematics?
 - 1B. What do teachers know and believe about using computers and related technologies to teach mathematics?
 - 1C. How do teachers use computers to teach mathematics?
2. What other factors do teachers report affect the adoption of computers and related technologies for mathematics instruction?

The primary finding of the study is that teachers' knowledge and beliefs about mathematics and about teaching and learning of mathematics influence the way computers are used or not used in the classroom.

Teachers who view mathematics conceptually seem to be more open to new ideas, flexible, and comfortable with computers -- making efforts in integrating computers into the existing curriculum -- whereas teachers who view mathematics as a set of rules and procedures rely heavily on textbooks and are not making efforts toward using computers for instruction. Due to their over reliance on textbooks, these teachers seem

to be threatened that computers will remove them from the textbooks and possibly lead them to "unfamiliar territory."

The teachers' knowledge and beliefs about mathematics, teaching and learning mathematics, students, classroom management, and the potential role of computers in mathematics instruction interplay with other complex phenomena mentioned in the conceptual framework. The study supported the assumption that teachers' knowledge, beliefs, and convictions ultimately influence their actions in the classroom. In sum, teachers' views about mathematics, teaching and learning mathematics, type and nature of students, and classroom interactions influence the use of computers in mathematics instruction.

Implications for Practice

This study makes a conceptual contribution for educational reform. This contribution has three implications for practice. First, it confirmed that teachers' knowledge of mathematics and beliefs about teaching and learning of mathematics influence the way computers are used in the classroom (refer to Conceptual framework in Chapter One and Figure 1). Second, it is apparent that teachers who participated in this study followed the footsteps of their own teachers in the classroom. If computers are truly educational tools for the future, it becomes absolutely necessary that teacher educators ensure that pre-service mathematics students are grounded in using computers for instruction. Third, information about the potentials of the technology based on teachers' levels of skills, demands, and instructional goals and objectives should be provided to current teachers. The information provided should be

consistent with teachers' knowledge and beliefs about the subject-matter and the potential role of the instructional tool before such a tool is even introduced in their classrooms.

From this study I have learned that the computer is not just a piece of new equipment added to the classroom; I perceive that a computer has some values and practices embedded within it. Once these values and practices challenge the existing practice and culture of the classroom, then there is problem of accommodation (Hodas, 1993). These values and practices mean different things to different teachers, and the way computers are used or not used in instruction depends on the teachers' knowledge about mathematics -- their preconceptions about teaching mathematics, their conceptions about the learner and learning, teachers' expectations of students, and teachers' beliefs and attitude toward classroom management and social interactions during the learning process.

Successful integration of this educational tool into the curriculum means confronting teachers' knowledge and beliefs. That means, consulting with teachers during planning and throughout the phases of development of the instructional software and the implementation process. The study recognizes the difficulties in developing any universal software that will satisfy all teachers, therefore, software development should be customized to serve the educational purpose of the user. This may be critical for the successful use of computers in teaching mathematics for understanding.

Based on the information provided by this study, teachers [who are programmers] like Kayce are likely to be "turned off" due to shift from teaching computer programming to integrating tool programs into existing curriculum. To

recapture their interests, it may be necessary to provide additional training that will help them make good transition from being programmers to integrators.

Teachers who share the same views with Robinson -- who still regard the computer as a distraction in the classroom, and who do not believe that computer has any positive effects on student learning, should be provided with practical demonstrations using concrete examples of the current units in their mathematics curriculum. This negative view about computers is consistent with that of most teachers, especially the low or non-users (Hall & Rhodes, 1986). My conclusion about this line of thought is not that the accounts of the computer enthusiasts are wrong, but rather, that good practice has not been widely implemented -- at least, no significant success in high school mathematics has been documented or experienced within this school district studied. Some researchers regard this resentment toward technology from teachers as generally healthy because it is a first step toward change; and it leads teachers to re-appraise the curriculum (Olson & Eaton, 1986). Hawkins and Sheingold (1986) argue a different view about the difficulty teachers encounter when using computers to introduce problem solving skills that were not in the regular curriculum and could not easily be monitored or assessed. Hawkins and Sheingold argue that teachers are frustrated because they need more than simply having more and better software or hardware. Rather, they need new curriculum with technological learning tools built-in, for example, the *Geometric Supposer*, *Excel*, *Mathematica* or *Graphing tools*.

This study also confirmed that computers are not a useful tool until they are used in a way that improves teaching and learning in the classroom. However, computer integration like other educational change asks teachers to change their pedagogy to accommodate a different delivery system and face a

different approach to teaching and learning of mathematics that utilize higher cognitive strategies. It seems unlikely that this sort of critical change can ever take place without thoughtful consideration of teachers' knowledge and beliefs and the role they play in shaping instruction. Reformers cannot simply tell teachers to teach differently, for as I have observed, there is "no ready prescription for thoughtful teaching" (Putnam et al., 1992). For any meaningful change, teachers need guidance and every necessary support from policy makers, administration, and teacher educators, since teachers are both the objects and agents of change (Cohen, 1990). Other implications for practice include:

1. Studies have documented that in terms of knowledge about the practice of teaching, teachers often represent the best "clinical expertise" available (Czajkowski & Patterson, 1980). Unfortunately, the same teachers are often discounted as primary resources for one another in the eyes of the administrators. It is important for administrators, teacher educators and "gatekeepers" to recognize the knowledge and beliefs of teachers before introducing any innovation into schools. Teachers' background will help to provide information necessary for professional development. For instance, this study has indicated that mathematics teachers may need a practical demonstration [preferably in their classroom] using units from the mathematics curriculum to show how computers could be used in the classroom.
2. Leaders of school districts should show a meaningful and genuine interests in the implementation of computers in the classroom. It is a common experience that most teachers who are proficient users of

computers are motivated by their peers, type of leadership, and the availability of computers. Such environment provide teachers the opportunity of interacting with other users in the same working environment (Sheingold & Hadley, 1990). Kagan (1992) found that as teacher's classroom experience grows richer and more coherent, it begins to form a highly personalized pedagogy. This positive attitude and good feeling in turn motivates other non-users.

3. Teachers should be helped with thoughtful and practical discussions of what activities are possible with computers in order to prepare students to increase mathematical understanding. Teachers have done well whenever they are confident about what they know. McMeen (1986) suggested that teachers' morale is usually high when they perceive themselves to be in control of their work. A tool that is consistent with their beliefs is likely to be actively sought, while those perceived as threats will be rejected. Stark et al. (1989) showed that even university teachers confessed that the strongest influence on the way they organize their instruction was their own beliefs and experience concerning their field of expertise.
4. The responses of teachers in this study echo the findings of other research in terms of teachers' fears, interpretation and concerns about educational change that threatens their beliefs [refer to Chapter Two]. Teachers are familiar and entrenched with hierarchical views of learning and development. For instance, teachers at high school definitely expect their freshmen to be familiar with the use of technology in mathematics

instruction. Where this is lacking, there is the tendency for teachers to doubt the overall purpose of using technology in mathematics instruction and may neglect the overall interest in instructional computing. Already, without technology, all the teachers complained about how ill-prepared the students are for high school mathematics.

5. For successful implementation of instructional computing, those who pressure teachers for content coverage and test scores need to be aware that such guidelines and pressures without adequate or appropriate curricular modifications only result in teachers selling students short of what learning is all about. This concept of educational achievement will only continue to widen the gap between what our future leaders are supposed to know and the type of problems that will challenge their intellect.

Clearly the study has shown that the teachers studied were at different levels of using computers for instruction. In analyzing the data, it was possible to classify teachers according to their knowledge and experience about instructional computing into the following categories: a) non-users, b) low integrators, c) medium integrators, and d) high integrators. Teachers' various levels of computer use seem to correlate with their different position at the wheel of change process as proposed by Fossum (1989). Fossum stated that there are four levels of change with four stages or phases within each level of the change process. The levels are: individual, group, institution, and organization. And the stages are: denial stage, resistance stage, adaptation stage, and the involvement stage.

The denial stage: People refuse to acknowledge the change process due to lack of knowledge and belief. Robinson is an example, because he does not believe that computers are necessary for high school mathematics, and he is not very knowledgeable about the use of computers for instruction.

The resistance stage: People resist change by being negative about it to outright opposing it. At this stage most of the would-be change agents seem to be helpless, losing control and power, experiencing some grief and having a feeling that the change will likely be a disaster. Bebe and Kayce fall into this category. While Bebe resists because he has no knowledge of instructional computing, Kayce resists because the emphasis has shifted from computer programming to tool applications which is not congruent to his existing beliefs.

The adaptation stage: People are in the process of acceptance.

The involvement stage: The change agents are actively involved in the change process. Vesta, Tomia and Obed are examples.

Computers may continue to remain at the periphery of teaching for a long time if the initiative to integrate computers into teaching is left to teachers alone. Teacher educators and administrators need to be aware and should recognize that teachers at different levels of understanding have various concerns. It is important to speculate that some teachers may not likely use computers for instruction for obvious reasons. Such teachers should not be coerced into using

computers because they could be used in a narrow way that does little or nothing to improve the mathematics learning environment. Policy makers should provide well defined guidelines that clearly state the purpose for using computers. These guidelines should determine what aspects of mathematics are suitable for computer use. Resources such as integrated curriculum and technical assistance should be provided to teachers (the ultimate users) who may need some guidance especially at the early stage of involvement.

Vesta, Tomia, and Obed -- the teachers who used computers for instruction --believe that computers change the dynamics of the classroom, which is consistent with the findings of Plomp and Pelgrum (1992). These teachers confirmed that the introduction of computers in classrooms cause some fundamental and conceptual changes in teaching strategies, different classroom and school organization, different roles and tasks for teachers, and new relationships between students and teachers. However, when teachers that participated in this study were observed, they ran into difficulties in using computers in more creative ways that were different from being mere teaching aids. These collective responsibilities should be taken into consideration when planning for computer implementation in the classroom.

Issues for Further Research

1. This study examined only six high school teachers in two schools within the same school district. Further studies should extend this work to examine more teachers in different districts.
2. Further studies should identify the intangible factors that constitute barriers to the successful implementation of instructional computing in

schools especially in mathematics classrooms. These intangible factors include such issues like “who gets what”, “who attends training”, “what type of training”, “who provides the training” etc.

3. A study that is conceptually drawn from the “expert and novice” knowledge base and classroom management strategies should be conducted to identify what makes expert teachers successful computer users. This study should examine how these expert teachers confronted their knowledge and beliefs and how they overcame the initial overarching problems that novice teachers are likely to face.
4. Another long term study should monitor or document the performance of students who were taught by expert computer users in mathematics to show how these students differ from students who were taught by non computer users in the traditional classroom.

Conclusion

The introduction of computers in schools has raised some concerns about teachers’ expectations, hopes and fears for recreating interesting ways of teaching and learning of mathematics and science and innovating education in general. The study revealed that any technology that was intended to empower teachers should be consistent with teachers’ knowledge and beliefs, and if possible less complex to manipulate. Much of what was learned showed that it is quite obvious that computers are far from being a tool for regular use in the daily school lives of students, especially in mathematics. Not only are very few

teachers use computers regularly, but also computers tend to be used in narrow ways that are reminiscent of the traditional method of teaching.

The most interesting finding is, teachers who view the learning of mathematics from the conceptual standpoint embrace the use of technology as a tool that will extend their knowledge and articulate these concepts more clearly for students understanding.

Conversely, teachers who consider mathematics as step-by-step procedural subject believe that technology should only be used for purposes that emphasize the important steps and recognize the right or wrong answers through either drill-and-practice or remedial activities. However, it is important to note that, it was a common experience that even teachers who lean toward conceptual teaching rather than repeating the didactic steps in mathematics, had difficulties in teaching mathematics in more meaningful ways. Based on the information provided by this study, it is not out of place to speculate that teachers who are "weak" in mathematics are very likely to encounter greater difficulties with instructional computing, and might put up tougher resistance toward this new challenge.

APPENDICES

APPENDIX A

PRIMARY INTERVIEW QUESTIONS

The primary purpose of the interview is to obtain as complete a statement about the teacher's knowledge of high school mathematics and his/her beliefs about the role of technology as a tool for instruction as seen by the respondent as is possible. A secondary interest is to become more knowledgeable about other factors (apart from his/her knowledge and beliefs) which might influence teacher's decision on how to use technology for math instruction.

Introduction

Thank you for agreeing to participate in this research project with me. I would like to tape today's interview in order to allow myself to listen and reflect on your thinking in this area. I am assuring you that neither your identity as a participant, nor the identity of your class or school will be made known to anyone except me and my advisor. Today in this first interview, I would like to ask you some questions to help better understand your conceptions of mathematics as a discipline, teaching and learning mathematics, as well as what you know and believe about the role of using technology (especially computers) for mathematics instruction. There are no "right or wrong" answers

in this interview. My goal is to understand your conceptions about mathematics, teaching and learning mathematics and how and where technology fits in.

Interview Questions

1. How many years have taught math in high school?
2. At what grade levels have you taught math?
3. What grade levels do you currently teach?
[Item 1-3 are background questions]
4. Based on your experience, what do you think is important that students should learn in high school mathematics? [Probe]
5. To achieve (item 4), what do you think students need to do to learn what is important in mathematics?
6. In your opinion what are the dispositions or ways of thinking mathematically that are most important for teaching math in high school?

[Probe for the logic behind the reasons and the relationship to his practice.

Further probe, how do you demonstrate or portray the importance of math (according to your response) in your classroom -- in terms of teaching the subject-matter?]

Since you teach different courses in mathematics, do you see any common threads that run through many of the topics you teach? What are the threads?

[Items 4 & 5 deal with the overall goal for high school mathematics -- from the teacher's perspective]

7. As a follow-up to the above question (item 5), what would you want your student to learn in this course? Or, what are your goals for your students in this course?
8. What do you assume your students should bring along when they enter your class? Why is it important? If they do not what do you do?
9. You mentioned before (item 5) What you want your students to learn, are they all in the curriculum? What topics (ideas) are important but not contained in the curriculum? What do you do to cover such important topics?

[Probe, if yes, does your response depend on the curriculum content? Why (or why not)?

If no, why? How do you cover the materials in the curriculum? How do you students measure in the standardized tests? What do you want your students to learn that is not reflected on these tests? Is there math tested which you do not teach? why? Probe for logic, relationship and consistency?]

[Items 6-8 explain: what is currently going on in the classroom and why the teacher has chosen to do so. It also helps me to understand his/her knowledge and beliefs about high school mathematics. The probes help to identify a pattern/consistency of what the teacher believes (as mentioned in item 4) and what he actually does in the classroom.]

10. Are there any aspects of math about which you feel strongly but about which the curriculum does not cover? Which objectives do you wish are deleted? Which objectives would you like see added?
11. What suggestions have you received from other teachers or district staff about what should be covered in math? Or is there any math you teach that they would not or want you to omit?

[Items 9 & 10 help to probe if there is any conflict between teacher's beliefs and the existing curriculum, otherwise, it can be skipped]

Technology

My main focus in this study is to understand how best technology could be used for high school mathematics instruction.

12. In an ideal situation, how would you like computers to be used as a tool for teaching mathematics in high school?

12.1 How would what you described above fit into the following teaching/learning/students

-learning/cognitive development

-social-emotional outcomes (interest,
motivation, self-concept)

-peer relationships

-individual differences (those who benefit
enormously, and those who dislike
computers)

-teacher

relationship with students

educational role in classroom (do you teach
differently because of computer, if yes, in what
ways?)

-personal cost/sacrifice

Repeat most of the probing questions of why and
how?

-curriculum

goals

content

[Item 11 explains teacher's beliefs and perceptions of what computers suppose to be doing. The items under 11.1 are probes that depend on teacher's responses].

13. Are you currently using computers for mathematics instruction?

14. How do you use computer(s) in your classroom?

-- in what activities?

-- software - source and adequacy? Probe, Why did

you choose this particular software?

-- How is it different from the traditional way of

teaching?

-- how do your students interact with it? What software are you using this year? Why are you using them? and how are you using them?

[Items 12 & 13 describe teacher's current practice. The probes help to confirm or contradict teacher's perceptions -- see item 11 above]

15. Apart from what you mentioned before, are there other ways you think computers should be used in teaching/learning mathematics? (Probe for why or why not. Why is he/she not doing it in his/her classroom)?

16. How do the materials you teach with computers fit into the curriculum? If yes, how? If no, how do you compromise that with the curriculum?

[Items 14 & 15 are probes that demonstrate teacher's knowledge and understanding of both the tool and the subject matter]

17. If you have unlimited resources, what would you want to happen in your classroom with computers? What do anticipate will happen in the future?
18. If you were advising a teacher who was about to begin to use computer in the classroom, what advice would you give?
19. If you were to advise your fellow mathematics teacher who is not using computer for instruction, what would you tell him/her? What do think he/she is missing for not using computer for instruction? What area is the use of computer particularly important?

[Items 17 & 18 are probes that help teachers reflect on the ways they have been thinking and using computers for instruction. It may surface the constraints/benefits associated with the use of computers in mathematics instruction].

20. What other factors (both internal or external) do you consider important that promote/restrict the use of computers for mathematics instruction in high school.

[Item 19 addresses the second main research question #2]

These questions are drawn from 'Content Determinant' by Porter et al. (1988); Kennedy et al. (1993); and Sheingold et al. (1981).

APPENDIX B

PRE-OBSERVATION INTERVIEW

Teacher _____

Observer _____

Date _____

A. The Session

1. Could you tell me a little about what you are planning to do when I observe your class?
2. Can you tell more about what your students will actually be doing in the class I intend to observe?
3. Why did you decide to do that? How does it relate to the rest of your plan in mathematics?
4. Is there anything in particular you are hoping to achieve in the classroom?
5. How likely is that (the specifics mentioned in q.4) will happen?
What will it depend on?
What might upset your plan?

6. Will this be difficult for any of your students?

Why?

7. Is there anything I should especially pay attention to while I'm in the classroom?

APPENDIX C

OBSERVATION FORM

Describe the class; note the class-size, number of computers, arrangement -- when they use the lab and class and why, whether student in groups or independently. Is the teacher telling or moves around watching how the kids interact with the technology? If students work in groups, how do they work within the group?

Narrative description: describe the lesson. The topic and the tasks.

Instructional materials: the type of software, and how it was used during the lesson?

Mathematics instruction: the goal; whether the mathematical meanings of the content emphasized in the lesson (give a specific example); the procedure -- in what way?

How is the technology used? Is the role of technology emphasized (is it used to un-pack a complex mathematical ideas or solve mathematical algorithm, construct graphs, find relationships, etc.) In what ways?

Where students comfortable with the technology? Are they familiar with the software? Are they exploring new mathematical ideas or they looking for right or wrong answers with the technology? Are they interested in computer games rather than using it to achieve the goal/objectives of the lesson.

What kind of questions are asked by the teacher or the students? Find out whether the students could have moved faster or understood better if they were to operate without the technology?

What do students do with the computer that seem(s) okay to the teacher?

While in the class, try to remember what and how the teacher reported how the technology is used in classroom? Looking out for patterns, constraints, consistency, and common mathematical knowledge/concept that runs through the lesson? In what ways and give specific examples.

APPENDIX D

POST OBSERVATION QUESTIONS

1. How did you feel things went in class?
How did things compare with what you had expected?
Did anything surprise you?
Was there anything you were particularly pleased about?
What; why?
Did anything disappoint you? What; why?

2. I noticed that you said/did -----
Why did you do that?
Does it have any particular advantages or disadvantages
(benefits or draw backs)?

3. I noticed that students where divided/not divided into groups.
Why? (or why not?)
Do you avoid or rely on groups most of the time?
Why?
If groups: How were the groups formed?
Do ever move students from one group to another?

4. I have only been able to observe this one day. Was the session typical of what you're doing in math these days?
If yes: Did you do anything special because you I knew I would be there?
If no: How is today's session different from usual?
5. I noticed _____. Why is that or why did it occur?
6. What mathematical concept/principles or idea/goal did you want the students to understand? Why?
7. What did the technology help them to achieve? Generally, if you reflect on your class instruction, is there anything you could have liked to change/add or delete? Why and how?
8. What major factors influenced your teaching style -- ways of using of technology?
9. When and how do you prepare your lesson?
What was the biggest challenge? What might characterize good computer use in the classroom?

APPENDIX E

TEACHERS' KNOWLEDGE AND BELIEFS ABOUT THE USE OF COMPUTERS IN HIGH SCHOOL MATHEMATICS

OBSERVATION AND INTERVIEW CONSENT FORM

This research is a partial fulfillment of my doctoral program. The goal of the research is to better understand the relationships between teachers' knowledge and beliefs about educational technology and how it is used in teaching mathematics in high school.

As part of the study, I would like to interview you about your knowledge and beliefs about the role of educational technology (especially computers) for teaching and learning of mathematics, classroom management, and student interaction in high school. At most, you will be asked to participate in a total of three hours or less of interview, to be arranged at your convenience. The interviews will be tape-recorded.

I would like to observe your class during regular instruction. The class session to be observed will be determined by you. I will tape-record the lesson I observe. The total amount of observation will not be more than two hours. Portions of the audio tapes will be transcribed for analysis.

Your participation in this research is voluntary. You may elect not to participate at all or not to answer any questions without any penalty to you.

All results of this research will be treated with strict confidence. You, your students, and your school will not be identified by name on any transcripts or in any reporting of this research.

If you desire further information about the study, you may call me, Clifford Akujobi, at (517) 355-6148, or my advisor, Dr. Ralph Putnam, at (517) 353-0637. Or you may write me or Dr. Putnam at: College of Education, Michigan State University, East Lansing, MI 48824-1034.

Clifford Akujobi

I agree to participate in this study. I understand that I will not be identified in any analysis or reporting of this research, and I am free to discontinue my participation at any time.

Signature: _____ Date: _____

Printed Name: _____ Date: _____

REFERENCES

REFERENCES

- Ames, R. (1983). Teachers' attributions for their own writing. In J. Levine & M. Wang (Eds.), Teacher and Student Perceptions: Implications for Learning. Hillsdale, NJ: Erlbaum.
- Anyon, J. (1981). Social class and school knowledge. Curriculum Inquiry, 11, 3-42.
- Aworuwa, B. O. (1994). A qualitative study of faculty's perceptions of computer use for teaching and the impact on teaching and learning. Unpublished doctoral dissertation, Michigan State University, East Lansing, MI.
- Ball, D. (1988a). Knowledge and reasoning in mathematical pedagogy: Examining what prospective teachers bring to teacher education. Unpublished doctoral dissertation, Michigan State University, East Lansing, MI.
- Ball, D. L. (1990). Reflections and deflections of policy: The case of Carol Turner. Educational Evaluation and Policy Analysis, 12, 247-259.
- Ball, D. L. (1990). With an eye on the mathematical horizon: Dilemmas of teaching elementary school mathematics (Craft Paper 90-3). East Lansing, MI: National Center for Research on Teaching Education, Michigan State University.
- Ball, D. L. (1991). Research on teaching mathematics: Making subject-matter knowledge part of the equation. In J. Brophy (Ed.), Advances in research on teaching: Vol. 2. Teachers' knowledge of subject matter as it relates to their teaching practice (pp. 1-48). Greenwich, CT: JAI Press.
- Ball, D. L., & McDiarmid, G. W. (1990). The subject-matter preparation of teachers. In W. R. Houston (Ed.), Handbook of Research on Teacher Education, New York: Macmillan.
- Ball, D. L., & Rundquist, S. S. (1993). Collaboration as a context for joining teacher learning with learning about teaching. In D. K. Cohen, M. W. McLaughlin, & J. E. Talbert (Eds.), Teaching for understanding: Challenges for policy and practice (pp. 13-42). San Francisco: Jossey-Bass.

- Barker, B. (1986). The role of the microcomputers in rural schools. Rural Educator, 8(1), 1-3.
- Barker, B. (1991). Distance Education in the United States: Technology strengths, weaknesses, and issues. Paper presented at the annual international conference on distance learning, United States Distance Learning Association, Washington, DC.
- Becker, H. J., (1985). How schools use microcomputers: Summary of the first national survey. Baltimore, MD: Center for Social Organization of Schools, The John Hopkins University.
- Bereiter, C., & Scardamalia, M. (1994). Classroom lessons: Integrating cognitive theory and classroom practice. In K. McGilly (Ed.), (pp. 291-309), Cambridge, MA: MIT Press.
- Berlak, A., & Berlak, H. (1981). Teachers working with teachers to transform schools. In J. Smith (Ed.), Educating Teachers: Changing the Nature of Pedagogical Knowledge, (pp. 169-178). New York: Falmer.
- Biklen, S. K., & Bogdan, R. (1986). On your own with naturalistic evaluation. In D. D. Williams (Ed.), Naturalistic Evaluations (New Directions for Program Evaluation), 30, 93-101. San Francisco: Sage.
- Bogdan, R. C., & Biklen, S. K. (1982). Qualitative research for education: An introduction to theory and methods. Boston: Allyn & Bacon.
- Borasi, R. (1988). An Inquiry into the Nature of Mathematical Definitions. Unpublished manuscript, University of Rochester.
- Borasi, R., & Siegel, M. (1990). Reading to learn mathematics: New connections, new questions, new challenges. For the Learning of Mathematics -- International Journal of Mathematics Education, 10(3), 9-16.
- Borko, H., & Putnam, R. T. (in press). Expanding a teacher's knowledge base: A cognitive psychological perspective on professional development. In T. Guskey, & M. Huberman (Ed.), New paradigms and practices in professional development.
- Borko, H., & Putnam, R. T. (in press). Learning to teach. In D. C. Berliner, & R. C. Calfee (Ed.), Handbook of Educational Psychology (New York: Macmillan.
- Boyer, E. L. (1984). High school: A report on secondary education in America. The Education Digest, pp. 39.

- Boyer, E. L. (1990). Scholarship reconsidered: Priorities of the Professoriate. Princeton, NJ: The Carnegie Foundation for the advancement of Teaching.
- Brophy, J. (1983). Research on the self-fulfilling prophecy and teacher expectations. Journal of Educational Psychology, 75, 631-661.
- Brophy, J. (1986). Teacher influences on student achievement. American Psychologist, 41, 1069-1077.
- Brophy, J. E. (1988). Research on teacher effects: Uses and abuses. The Elementary School Journal, 89(1), 1-21.
- Brophy, J. (1991). Advances in Research on Teaching: Vol. 2. Teachers' subject matter knowledge. Greenwich, CT: JAI Press.
- Brophy, J., & Good, T. L. (1986). Teacher behavior and student achievement. In M. C. Wittrock (Ed.), Handbook of Research on Teaching, (3rd ed., pp. 328-375). New York: Macmillan.
- Brown, C. A. & Baird, J. (1993). Inside the teacher: knowledge, beliefs, and attitudes. In P. S. Wilson (Ed.), Research Ideas for the Classroom: High School Mathematics, (pp. 245-259), New York: Macmillan.
- Brown, C. A. (1986). A study of the socialization to teaching of a beginning secondary mathematics teacher (Doctoral dissertation, University of Georgia, 1985). Dissertation Abstracts International, 46, 2605A.
- Buddin, H. R. (1991). Technology and the teachers' role. Computers in the Schools. Vol. 8(1-3), (pp. 15-26).
- Bychowski, D. K., & Van Dusseldorp, R. (1984). Computer literacy and use among elementary classroom teachers. ERIC. (ED 249938).
- Calderhead, J. (1984). Teachers' Classroom decision Making. London: Holt, Rinehart.
- California State Department of Education. (1985). Mathematics Framework. Sacramento: Author.
- California State Department of Education. (1987). Mathematics Model Curriculum Guide. Sacramento, CA: Author.
- California State Department of Education. (1991). Mathematics Framework for California Public Schools. Sacramento, CA: Author.
- Callister, Jr., T. A. & Dunne, F. (1992). The Computer as Doorstep: Technology as Disempowerment. Phi Delta Kappan, (4), p324(3).

- Carpenter, T. P., Fennema, E., Peterson, P. L., & Carey, D. A. (1988). Teachers' pedagogical content knowledge of students' problem solving in elementary arithmetic. Journal for Research in Mathematics Education, 19(5), 385-401.
- Cazden, C. B. (1986). Classroom discourse. In M. C. Wittrock (Ed.), Handbook of research on teaching (pp. 432-463). New York: Macmillan.
- Cetron, M. (1985). Schools of the future: How American business and education can cooperate to save our schools. New York: McGraw-Hill.
- Chandra, P. (1987). How do teachers view their teaching and use of teaching resources? British Journal of Educational Technology, 18(2), 102-111.
- Choo, M. L., & Cheung, K. C. (1990). On meaningful measurement: Junior college pupils' anxiety towards computer programming. J. Educational Technology Systems Vol. 19(4), (pp. 327-343).
- Clark, C. M. (1988). Asking the right questions about teacher preparation: Contributions of research on teacher thinking. Educational Researcher, 17(2), 5-12.
- Clark, C. M., & Peterson, P. L. (1986). Teachers' thought processes. In M. C. Wittrock (Ed.), Handbook of Research on Teaching (3rd ed., pp. 255-296). New York: Macmillan.
- Clement, F. J. (1981). Affective considerations in computer-based education, Educational Technology, 21, (pp. 28-32).
- Cohen, D. (1988). Educational technology and school organization. In R. Nickerson & P. Zoghbiates (Eds.), Technology in Education: Looking toward 2020. Hillsdale, NJ: Lawrence Erlbaum.
- Cohen, D. (1990). Policy and practice: The classroom impact of state and federal policy. Unpublished manuscript, Michigan State University.
- Cohen, D. K., & Ball, D. L. (1990). Policy and Practice: An Overview. Effects of State-Level Reform of Elementary School Mathematics Curriculum Practice (Research Report 90-14). East Lansing, MI: National Center for Research on Teacher Education, Michigan State University.
- Cohen, D. K., & Ball, D. L. (1990). Relations between policy and practice: A commentary. Educational Evaluation and Practice Analysis, 12(3), Fall 1990, 249-56.
- Collins, A. (1991). The role of computer technology in restructuring schools. Phi Delta Kappan 73(1), p28(9).

- Confrey, J. (1990). A review of the research on student conceptions in mathematics, science, and programming. In C. B. Cazden (Ed.), Review of Research in Education (Vol. 16, pp. 3-56). Washington: American Educational Research Association.
- Cooney, T. J. (1985). A beginning teacher's view of problem solving. Journal for Research in Mathematics Education, 16(5), 324-336.
- Cuban, L. (1986). Teachers and Machines: The classroom use of Technology since 1920. New York: Teachers College Press.
- Cuban, L. (1990). Four stories about national goals for American Education. Phi Delta Kappan, 72(4), 264-71.
- Cumming, A. (1988). Change, organization, and achievement: Teachers' concerns implementing a computer learning environment. Journal of Educational Technology Systems, 17(2), (pp. 141-163).
- Czajkowski, T., & Patterson, J. (1980). Curriculum change and the school. In A. W. Foshay (Ed.), Considered action for curriculum improvement. (pp. 158-175). Alexandria, VA: ASCD.
- Darling-Hammond, L., & Wise, A. E. (1985). Beyond standardization: State standards and school improvement. Elementary School Journal, 85(3), 316-36.
- Dewey, J. (1916). Democracy and Education. New York: Macmillan.
- Dossey, J. A., Mullis, I. V. S., Lindquist, M. M., & Chambers, D. L. (1988). NAEP: The mathematics report card: Are we measuring up? Princeton: Educational Testing Service.
- Doyle, W. (1983). Academic work. Review of Educational Research, 53(2), 159-199.
- Doyle, W. (1986). Classroom organization and management. In M. C. Wittrock (Ed.), Handbook of Research on Teaching (3rd ed., pp. 392-431). New York: Macmillan.
- Elbaz, F. (1983). Teacher thinking: A study of practical knowledge. New York: Nichols.
- Even, R. (1993). Subject-matter knowledge and pedagogical content knowledge: Prospective secondary teachers and the function concept. Journal for Research in Mathematics Education, 24(2), 94-116.
- Fenstermacher, G. D. (in press). The knower and he known in teacher knowledge research. In L. Darling-Hammond (Ed.), Review of Research

- of Education Vol. 20. Washington, D.C.: American Educational Research Association.
- Fossum, L. B. (1989). Understanding organizational change: Converting theory to practice. Los Altos, Calif.: Crisp.
- Fullan, M. (1982). The Meaning of Educational Change. New York: Teachers College Press.
- Gagne, R. (1977). The Conditions of Learning, (3rd ed.). New York: Holt, Rinehart & Winston.
- Ganguli, A. B. (1990). The microcomputer as a demonstration tool for instruction in mathematics. Journal for Research in Mathematics Education, 14, (pp. 19-29).
- Ganguli, A. B. (1992). The effect on students' attitudes of the computer as a teaching aid. Educational Studies in Mathematics, 23, (pp. 611-618).
- Gearhart, M., Herman, J. L., Baker, E. L., Novak, J. R., & Whittaker, A. k. (1990). A new mirror for the classroom: A technology-based tool for documenting the impact of technology on instruction. A Paper presented at Apple classrooms of Tomorrow Symposium in Cupertino, Calif.
- Goldman, E., & Barron, L. (1990). Using hypermedia to improve the preparation of teachers. Journal of Teacher Education. 41(3), (pp. 21-31).
- Good, T. L. (1987). Two decades of research on teacher expectations: Findings and future directions. Journal of Teacher Education, 38(4), 32-47.
- Gross, N., Giacquinta, J., & Bernstein, M. (1971). Implementing organizational innovations. New York: Harper & Row.
- Grossman, P. L. (1990). The making of a teacher: Teacher knowledge & teacher education. New York: Teachers College Press.
- Hall, J., & Rhodes, V. (1986). Microcomputers in primary schools -- some observations and recommendations for good practice. London: King's College Center for Educational Studies, Educational Computing Unit.
- Hammersley, M. & Atkinson, P. (1983). Ethnography - Principles in nature. New York: Routledge.
- Hashweh, M. Z. (1986). An exploratory study of teacher knowledge and teaching: The effects of science teachers' knowledge of subject-matter and their conceptions of learning on their teaching (Doctoral dissertation, Stanford University, 1985). Dissertation Abstracts International, 46, 3672A.

- Hasselbring, T. S. (1991). Improving education through technology: Barriers and recommendations. Preventing School Failure, **3** 5(3), 33-37.
- Hawkins, J., & Pea, R. (1987). Tools for bridging the cultures of everyday and scientific thinking. Journal of Research in Science Teaching, **24**, 291-307.
- Hawkins, J., & Sheingold, K. (1986). The beginning of a story: computers and the organization of learning in classrooms. In Culbertson, J. and Cunningham, L. (Eds.), (pp. 40-58).
- Hawkrige, D. (1990). Computers in the third world schools: the example of China. British Journal of Education Technology, **2** 1 (1), 4-20.
- Heaton, R. M. (1992). Who is minding the mathematics content? A case study of a fifth-grade teacher. Elementary School Journal, **9** 3, 151-192.
- Herman, J. T., Heath, R. M., Valders, R. M., & Brooks, P. E. (1991). 1989-90 Research and Evaluation: Model Technology Schools Project. Los Angeles, Calif.: Center for the Study of Evaluation, UCLA Graduate School of Education.
- Heywood, G., & Norman, P. (1988). Problems of educational innovation: The primary teachers' response of using the microcomputer. Journal of Computer-Assisted learning, **4**(1), 34-43.
- Hodas, S. (1993). Technology refusal and the organizational culture of schools. Education Policy Analysis Archive. **1** (10), 1-19.
- Honey, M. & Moeller, B. (1990). Teachers' beliefs and technology integration: Different values, different understandings. Technical Report no. 6. Center for Technology in Education, New York, NY.
- Hoyles, J. R. (1993). Our children: Dropouts, pushouts, and burnout. People and Education, Newbury Park, Calif.: Corwin.
- Hoyles, C. (1982). The pupils' view of mathematics learning. Educational Studies in Mathematics, **1** 3(4), 349-372.
- Jones, S. (1985). The analysis of depth interviews. In R. Walker (Ed.), Applied Qualitative Research, (pp. 45-55). Brookfield: Gower Publishing Company.
- Kagan, D. M. (1992). Implications of research on teacher belief. In Educational Psychologist, **2** 7(1), 65-90.

- Kaput, J. J. (1992). Technology and mathematics education. In Grouws, D. A. (Ed), Handbook of Research on Mathematics Teaching and Learning: A Project of the NCTM. 515-556.
- Kennedy, M. M., Ball, D. L. & McDiarmid, G. W. (1993). A Study for Examining and Tracking Changes in Teachers' Knowledge. (Technical Series 93-1). East Lansing, MI: Michigan State University, National Center for Research on Teacher Learning.
- Kerr, S. T. (1991). Educational reform and technological change: Computing literacy in the Soviet Union. Comparative Education Review, **35**(2), 222-54.
- Knupfer, N. N. (1993). Teachers and educational computing: changing roles and changing pedagogy. In R. Muffoletto & N. N. Knupfer (Eds.), Computers in Education: Social, Political and Historical Perspectives, Cresskill, NJ: Hampton Press.
- Kozma, R. B. (1991). Learning with media. Review of Educational Research, **61**(2), 17-211.
- Kozma, R. B., & Johnson, J. (1991). The technological revolution comes to the classroom. Change, **23**, (pp. 10-23).
- Kulik, J. A., Bangert, R., & Williams, G. (1983). Effects of compute-based teaching on secondary students. Journal of Educational Psychology, **75**(1), 19-26.
- Lampert, M. (1985). How do teachers manage to teach? Harvard Educational Review, **55**, 178-194.
- Lampert, M. (1986). Teaching multiplication. Journal of Mathematics Behavior, **5**(3), 241-80.
- Lampert, M., & Ball, D. L. (1990). Using hypermedia technology to support a new pedagogy of teacher education. (Issue paper 90-5), East Lansing, MI: Michigan State University, The National Center for Research on Teacher Learning.
- Latour, B. (1986). Visualization and cognition: Thinking with eyes and hands. Knowledge and Society: Studies in the Sociology of Culture, **6**, (pp. 1-40).
- Leinhardt, G., & Greeno, J. G. (1986). The cognitive skill of teaching. Journal of Educational Psychology, **78**, 75-95.

- Mandinach, E. B. (1989). Model-building and the use of computer simulation of dynamic systems. Journal of Educational Computing Research, 5, 221-43.
- Marks, R. (1990). Pedagogical content knowledge: From a mathematical case to a modified conception. Journal of Teacher Education, 41(3), (pp. 3-11).
- Marx, R. W. (1978). Teacher Judgements of Students Cognitive and Affective Outcomes. Unpublished doctoral dissertation, Stanford University.
- McDonald, J. P. (1988). The emergence of the teacher's voice: Implications for the new reform. Teachers College Record, 89, 471-486.
- McMeen, G. (1986). The impact of technological change on education. In Hirschbuhl (Ed.), Computers studies: Computers in Education. Guilford, CT: The Dushkin Publishing.
- Mertz, M. (1978). Classrooms and Corridors. Berkeley: University of California Press.
- Miles, M. B. & Huberman, A. M. (1984b). Qualitative Data Analysis. Beverly Hills: Sage Publications.
- Naisbett, J. (1982). Megatrends: Ten new directions transforming our lives. New York: Warner Books.
- National Council of Teachers of Mathematics. (1989). Curriculum and evaluation standards for school mathematics. Reston, VA: Author.
- National Council of Teachers of Mathematics. (1991). Professional standards for teaching mathematics. Reston, VA: Author.
- National Governor's Association. Results in Education 1987: The Governors' 1991 Report on Education. Washington, D. C.: National Governors' Association, 1987.
- National Institute of Education. (1975). Teaching as Clinical Information Processing. (Report of Panel 6, National Conference on Studies in Teaching). Washington, D.C.: National Institute of Education.
- National Research Council. (1989). Everybody counts: A report to the nation on the future of mathematics education. Washington: National Academy Press.
- National Research Council. (1991). Moving beyond myths: revitalizing undergraduate mathematics. Washington, D.C.: National Academy Press.

- Newman, D. (1992). Technology as support for school structure and school restructuring. Phi Delta Kappan, Vol. 74(4), (pp. 308-315).
- Nickerson, R. S. (1988). On improving thinking through instruction. Review of Research in Education, 15, (pp. 3-57).
- Noddings, N. (1990). Constructivism in mathematics education. In R. B. Davis, C. A. Maher, & N. Noddings (Eds.), Journal for Research in Mathematics Education monograph number 4 - Constructivist Views on the Teaching and Learning of Mathematics. Reston, VA: National Council of Teachers of Mathematics.
- Novak, D. I., & Knowles, G. J. (1991). Beginning elementary teachers' use of computers in classroom instruction. Action in Teacher Education, 13(2), 43-51.
- O'Connor, B. (1992). Planning for the Technology-Rich Learning Environments of the Future. Learning Technologies Essential for Education Change. Council of Chief State School Officers. Washington D.C.
- O'laughlin, M., & Campbell, M. B. (1988). Teacher preparation, teacher empowerment, and effective inquiry: A critical perspective. Teacher Education Quarterly, 15(4), 25-53.
- Oakes, J. (1985). Keep track: How schools structure inequity. New Haven: Yale University Press.
- Oakes, J. (1990). Opportunities, achievement, and choice: Women and minority students in science and mathematics. Review of Research in Education, 16, 153-222.
- Office of Technology Assessment (1991). Federal funded research: Decisions for a decade. Congress of the U. S., Washington, D. C. Office of Technology Assessment.
- Office of Technology Assessment (1988). Power on! New Tools for Teaching and Learning (OTA-SET-379). U.S. Government Printing Office.
- Olson, J., & Eaton, S. (1986). Case studies of microcomputers in the classroom. Questions for curriculum and teacher education. Education and Technology Series.
- Patton, M. (1990). Qualitative Evaluation and Research Methods. Newbury Park, CA: Sage.
- Paulos, J. A. (1988). Innumeracy: Mathematical illiteracy and its consequences. New York: Hill and Wang.

- Payne, S. (1951). The Art of Asking Questions. Princeton, NJ.: Princeton University Press.
- Pelgrum, W. J., Reinen, I.A.M.J., & Plomp, Tj. (1993). Schools, teachers, students, and computers: A cross-national perspective. IEA-comped study, stage 2.
- Peterson, P. L. & Clark, C. M. (1978). Teachers' report of their cognitive processes during teaching. American Educational Research Journal, 15, 555-565.
- Plomp, Tj., & Pelgrum, W. (1992). Restructuring of schools as a consequence of computer use? International Journal of Educational Research, 17, 185-194.
- Plomp, Tj., & Pelgrum, W. J. (1991). Introduction of computers in education: state of the art in eight countries. Computers in Education, 17(3), p. 249-258.
- Plomp, Tj., & Pelgrum, W. J. (1993). Restructuring of schools as a consequence of computer use? International Journal of Educational Research, 19(2), (pp. 185-194).
- Porter, A., Floden, R., Freeman, D., Schmidt, W., & Schwille, J. (1988). Content determinants in elementary school mathematics. In D. A. Grouws, T. J. Cooney, & D. Jones (Eds.), Effective mathematics teaching (pp. 96-113). Reston, VA: National Council of Teachers of Mathematics.
- Posner, G., Strike, K., Hewson, P., & Gertzog, W. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. Science Education, 66(2), 211-27.
- Pratt, D. L. (1985). Responsibility for student success/failure and observed verbal behavior among secondary science and mathematics teachers. Journal of Research in Science Teaching, 22, 807-816.
- Prawat, R. S. (1992). Are changes in views about mathematics teaching sufficient? The case of a fifth-grade teacher. Elementary School Journal, 93, 195-211.
- Prawat, R. S., Remillard, J., Putnam, R. T., & Heaton, R. M. (1992). Teaching mathematics for understanding: Case studies of four fifth-grade teachers. Elementary School Journal, 93, 145-152.
- Putnam, R. T. (1992). Teaching the "hows" of mathematics for everyday life: A case study of a fifth-grade teacher. Elementary School Journal, 93, 163-177.

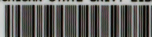
- Putnam, R. T., Heaton, R. M., Prawat, R. S., & Remillard, J. (1992). Teaching mathematics for understanding: Discussing case studies of four fifth-grade teachers. Elementary School Journal, **93**, 213-228.
- Putnam, R. T., Lampert, M., & Peterson, P. L. (1989). Alternative perspectives on knowing mathematics in elementary schools (Elementary Subjects Center Series No. 11). East Lansing, MI: Michigan State University, Institute for Research on Teaching.
- Putnam, R. T., & Borko, H. (in press). Expanding a teachers' knowledge base: A cognitive psychological perspective on professional development. In T. Guskey & M. Huberman (Eds.), New Paradigms and Practice in Professional Development.
- Ray-Taylor, R. J. (1991). Teachers' Interpretation and Use of State Achievement Test Results. Unpublished doctoral dissertation, Michigan State University, East Lansing, MI.
- Resnick, L. B. (1987). Constructing knowledge in school. In L. S. Liben (Ed.), Development and learning: Conflict or congruence? (pp. 19-50). Hillsdale, NJ: Erlbaum.
- Rockman, S. (1992). To lead or to Follow: The role and influence of research on technology. Learning Technologies Essential for Education Change. Council of Chief State School Officers. Washington D.C.
- Rosenthal, R., & Jacobson, L. (1986). Pygmalion in the Classroom: Teacher Expectation and Pupils' Intellectual Development. New York: Holt, Rinehart.
- Roth, K. (1984). Using classroom observations to improve science teaching and curriculum materials. In C. W. Anderson (Ed.), Observing science classrooms: Perspectives from Research and Practice. 1984 Yearbook of the American Association for the Education of Teachers in Science. Columbus, OH: ERIC Center for Science, Mathematics, and Environmental Education.
- Sarason, S. B. (1982). The Culture of the School and the Problem of Change. Boston, MA: Allyn & Bacon.
- Sarason, S. B. (1990). The Predictable Failure of Educational Reform. San Francisco: Jossey-Bass.
- Schmidt, W. H., & Kennedy, M. M. (1990). Teachers' and Teacher Candidates' Beliefs about Subject Matter and about Teaching Responsibilities. (Research Report 90-4). East Lansing, MI: Michigan State University, National Center for Research on Teacher Learning.

- Schoenfeld, A. H. (1985). Mathematical problem solving. Orlando, FL: Academic Press.
- Schoenfeld, A. H. (1988). When good teaching leads to bad results: The disasters of "well-taught" mathematics courses. Educational Psychologist, 23(2), 145-166.
- Schon, D. A. (Ed.), (1991). The reflective turn: Case studies in and on educational practice. New York: Teachers College Press.
- Schuh, & Whitt, (1992). Use of Qualitative Research Methods. Doctoral colloquium presented to the National Association of Student Personnel Administrators, Cincinnati, OH.
- Schwab, J.J. (1964). The structure of disciplines: Meanings and significance. In G. W. Ford & L. Pugno (Eds.), The Structure of Knowledge and the Curriculum. Chicago: Rand McNally.
- Seidman, I. E. (1991). Interviewing as qualitative research: A guide for researchers in education and the social sciences. New York: Teachers College Press.
- Sheingold, K. (1991). Restructuring for learning with technology: The potential for synergy. Phi Delta Kappan 73(1), (pp. 17-27).
- Sheingold, K. (1992). Technology integration and teachers' professional development. Learning Technologies Essential for Education Change. Council of Chief State School Officers. Washington D.C.
- Sheingold, K., & Hadley, M. (1990). Accomplished Teachers: Integrating Computers into Classroom Practice. New York: Bank Street College of Education, Center for Technology in Education.
- Sheingold, K., Kane, J., Endreweit, M., & Billings, K. (1981). Study of Issues related to Implementation of Computer Technology in Schools. New York: Bank Street College of Education.
- Shreiter, B., & Ammon, P. (1989). Teachers' thinking and their use of reading contracts. Paper presented at the annual meeting of the American Educational Research Association, San Francisco.
- Shuell, T. J. (1986). Cognitive conceptions of learning. Review of Educational Research. 56, 411-436.
- Shulman, L. S. (1983). Autonomy and obligation: The remote control of teaching. In L. S. Shulman & G. Sykes (Eds.), Handbook of Teaching and Policy. New York: Longman.

- Shulman, L. S. (1986a). Those who understand: Knowledge growth in teaching. Educational Researcher. **15**(2), 4-14.
- Shulman, L. S. (1988). Knowledge growth in teaching: A final report to the Spencer Foundation. Stanford, CA: Stanford University.
- Shulman, L.S., & Grossman, P. L.. (1987). Final Report to the Spencer Foundation (Technical Report of the Knowledge Growth in a Profession Research Project). Stanford, CA: School of Education, Stanford University.
- Simon, M. A. (1993). Prospective elementary teachers' knowledge of division. Journal for Research in Mathematics Education. **24**, (pp. 233-254).
- Stark, J. S., Lowther, M. A., Bentley, R. J., Ryan, M. P., Genthon, M., Martens, G., & Wren, P. A. (1989). Planning introductory courses: Influences on facility. Ann Arbor, MI: National Center for Research to Improve Post secondary Teaching and Learning, University of Michigan.
- Stein, M. K., Baxter, J. A., & Leinhardt, G. (1990). Subject-matter knowledge and elementary instruction: A case from functions and graphing. American Educational Research Journal. **27**, 639-663.
- Steinberg, R., Haymore, T., & Marks, R. (1985). Teachers' knowledge and structuring content mathematics. Paper presented at the annual meeting of the American Educational Research Association, Chicago.
- Thompson, A. G. (1984). The relationship of teachers' conceptions of mathematics and mathematics teaching to instructional practice. Educational Studies in Mathematics. **15**, 105-127.
- Thompson, A. G. (1992). Teachers' beliefs and conceptions: A synthesis of the research. In D. A. Grouws, (Ed.), Handbook of Research on Mathematics Teaching and Learning. New York: NCTM, Macmillan Publishing Company.
- Thompson, P. (1990). A theoretical model of quantity-based reasoning in arithmetic and algebra. A Revised Version of a Paper presented to the Annual Meeting of the AERA, San Francisco, CA.
- Thornburg, D. D. (1992). Learning alternatives: Technology in support of lifelong education. Learning Technologies Essential for Education Change. Council of Chief State School Officers. Washington D.C.

- Vernette, S. M., Orr, R., & Hall, M. H. (1986). Attitudes of elementary school students and teachers toward computers in education, Educational Technology. **26**, (pp. 41-46).
- von Glasersfeld, E. (1991). Radical Constructivism in mathematics education. Dordrecht, The Netherlands; Boston: Kluwer Academic.
- Wedman, J. F. (1988). Increasing the use of instructional media in the schools. Educational Technology. **28**(10), 26-31.
- Welch, W. W. (1979). Twenty years of science curriculum development: A look back. Review of Research in Education, **7**, 282-306.
- Wilcox, S. K., Schram, P., Lappan, G., & Lanier, P. (1991). The Role of a Learning Community in Changing Preservice Teachers' Knowledge and Beliefs about Mathematics Education (Research Report 91-1). East Lansing, MI: Michigan State University, National Center for Research on Teacher Education.
- Wilcox, S. K., Schram, P., Lappan, G., & Lanier, P. (1992). Influencing beginning teachers' practice in mathematics education: Confronting constraints of knowledge, beliefs, and context. (Research Report 92-1). East Lansing, MI: Michigan State University, National Center for Research on Teacher Education.
- Wilson, S. M., Shulman, L. S., & Richert, A. E. (1987). "150 different ways" of knowing: Representations of knowledge in teaching. In J. Calderhead (Ed.), Exploring teachers' thinking. (pp. 104-124). London: Cassell.
- Wood, T., Cobb, P., & Yackel, E. (1990). The contextual nature of teaching: Change in mathematics but stability in reading. Elementary School Journal. **90**, 497-513.
- Wood, T., Cobb, P., & Yackel, E. (1991). Change in mathematics teaching: /a case study. American Educational Research Journal. **28**, 587-616
- Woodrow, J. E. J. (1991). Determinants of student teacher computer literacy achievement. Computers and Education. **16**(3), (pp. 237-245).
- Zammit, S. A. (1992). Factors facilitating or hindering the use of computers in schools. Educational Research. **34**(1), 57-66.

MICHIGAN STATE UNIV. LIB



3129301409563