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AN EXPLORATORY STUDY OF THE IMPLEMENTATION OF AN EDUCATIONAL TECHNOLOGY IN TWO EIGHTH GRADE MATHEMATICS CLASSES

A Thesis in

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Sarah B. FitzPatrick

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We approve the thesis of Sarah B. FitzPatrick

Date of Signature

Alison A. Carr-Chellman
Associate Professor of Education
Thesis Advisor
Chair of Committee

Russell Faux
Director of Research and Evaluation
Riverdeep Interactive Learning
Special Member

J. Daniel Marshall
Associate Professor of Education

James F. Nolan
Associate Professor of Education

Kyle L. Peck
Professor of Education
Head of the Department of Adult Education, Instructional Systems, and Workforce Education

ABSTRACT

During the last decade US K-12 schools have approximately tripled their spending on increasingly powerful computers, expanded network access, and novel computer applications. The number of questions being asked by educators, policymakers, and the general public about the extent to which these technologies are being used in classrooms, for what purposes, and to what effects, has likewise increased. Recent research is characterized by an awareness that the process of implementing educational technologies in schools is much more human than technological and can only be understood in context. Exploring the human implementation process is thought to be one key to understanding how educational technologies find purchase and evolve in local classroom environments. This naturalistic inquiry explored the semester-long process of implementing an interactive learning system in two math classes in a rural mid-Atlantic Junior–Senior High School. Schwab's (1978) curriculum contexts (teacher, student, subject matter, milieux) provided loci for identifying, describing, and interpreting the students' and teacher's experiences of the interactive learning system. Data collection was based on field observations, periodic interviews with individual students and their teacher, exploratory and culminating focus group interviews with students, and document analysis. Grounded theory methods were used to analyze the data. I found that there was no significant change in the teacher's instructional model during her implementation of the interactive learning system. Conditions that supported the teacher in her decision to adopt the educational technology curriculum innovation did not sustain her instructional evolution during the implementation process. The teacher reached a point of *Implementation Impasse* while simultaneously using the traditional district-controlled teacher-proof curriculum and the interactive learning system with her two eighth grade math classes. The level of mismatch between the traditional math curriculum and the curriculum represented by the novel educational technology emerged as a critical factor influencing the implementation process. The students' primary implementation experiences focused on learner-control vis-à-vis the tools of the system, opportunities for spontaneous peer interactions, and increased motivation in the technology-enhanced math

class. I provide recommendations for future research and for the implementation of educational technologies in schools.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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CHAPTER 1

RESEARCH OVERVIEW

From the earliest instructional media innovations of the 1900s to the sophisticated, computer-based, and networked learning systems of the twenty-first century, more wide-eyed wonderment than results has marked the first decades of exploring what these educational technologies might offer schools (Salomon & Perkins, 1996, p. 111-112). Fueled by expectations for the transformation of classroom teaching and learning practices, investments by policy-makers and school administrators in educational technologies have steadily increased. The number of questions being asked about the extent to which these educational technologies are being used in classrooms, and for what purposes, has also increased (Smerdon et al., 2000). As one observer noted, there is something of a disconnect between policymakers' expectations and our understanding of how educational technologies are actually implemented in classroom environments (Lemke, 1998, as cited in Trotter, 1998). Recent research is characterized by an awareness that the process of implementing educational technologies in schools is much more human than technological and can only be understood in context. The present study proposes Schwab's (1978) four contexts for curriculum: teacher, student, subject matter, and milieu, as useful loci for exploring the contextualized process of implementing an educational technology in two eighth grade mathematics classes. I explicate the research questions using this framework, and I conclude the chapter with an overview of the purpose and significance of the present study.

Throughout the twentieth century, proponents of each new wave of instructional media have touted the benefits for children and the potential for educational transformation (Wartella and Jennings, 2000). As early as 1913, a sanguine Thomas Edison declared, "Books will soon be obsolete in the schools… It is possible to teach every branch of human knowledge with the motion picture. Our school system will be completely changed in the next ten years" (Saettler, 1968, p. 98). Although Edison's predictions for educational change were not realized, they found renewal in the form of the radio in the early 1930s. Referring to the instructional potential of radio and motion picture, the editor of publications for the National Education Association proclaimed, "Tomorrow they will be as common as the book and powerful in their effect on learning and teaching" (Morgan, 1932, p. ix). In the 1950s the demise of traditional instructional media (teacher, text) was once again forecast; educational broadcasting was seen as an effective, efficient means of satisfying the nation's instructional needs. By 1967 the Carnegie Commission on Educational Television concluded that such high expectations were largely unwarranted "the role played in formal education by instructional television has been on the whole a small one… With minor exceptions, the total disappearance of instructional television would leave the education system fundamentally unchanged" (p. 80-81).

Our faith in the potential of instructional media to leverage significant change in our classrooms and schools has been revitalized with the development of educational technologies. As instructional media have become more pedagogically sophisticated, expectations for their potential to transform classroom teaching and learning have increased accordingly. Educational technologies provide more representations of content and opportunities for interaction with this subject matter than traditional instructional media. The aforementioned instructional media (radio, film, instructional television) were introduced in classroom settings with the intention of supporting student interactions with content. The earliest teaching texts, programmed books, and teaching machines facilitated student interaction with subject matter by requiring students to provide overt responses to sequences of logically presented content delivered through a variety of instruments ranging from workbooks to computers (Burton, Moore and Magliaro, 1996). Subsequent individualized approaches to instruction emphasized mastery learning and self-pacing for students (Saettler, 1990). Computer Assisted Instruction (CAI) packages reinforce this emphasis on individualized student instruction by offering tutorials, simulations, drill and practice, and problem solving programs to facilitate student interaction with content. Networked systems (Wasser, McNamara and Grant, 1998) afford opportunities for students to learn from increasingly accessible, dynamic, and interactive school curricula. These interactive learning systems exploit the potential of electronic networks to support increasingly dynamic and collaborative learning environments by offering families of multimedia tools to support teaching and learning. Based on these increased opportunities for students to represent, and interact with, subject matter, the approach of the 21st century has brought a chorus of pronouncements that "the information society both requires and makes possible new forms of education" (Papert and Caperton, 1999).

Increasingly powerful computers, expanded network access, and novel computer applications have enlarged both investments in, and expectations for, the transformation of classroom teaching and learning. During the last decade US K-12 schools have approximately tripled their spending on educational technologies from $2.1 billion in 1990-1991 to a proposed $6.2 billion in 1999-2000 (Quality Education Data [QED], 1999). The ratio of students to computers has improved from 125 students per computer in 1984 to a ratio of 10 students per computer in 1997 (Coley, Cradler and Engel, 1998, p. 11). While investments in educational technologies have steadily increased, not enough money has been spent on educational research (Web Based Education Commission, 2000). In 1999 the U.S. government invested $313 billion on public K-12 education, but allocated less than 0.1% of that amount to determine what educational techniques actually work, and to find ways to improve them (Shaw, 2000). Improving educational outcomes by exploiting the appeal of challenging interactive learning technologies is a powerful motivation for such significant investments in educational technologies (Becker, 1998a), yet this ambition is not unprecedented in the history of instructional media. Even a cursory review of the impact of instructional media on educational outcomes reveals a significant disparity between the anticipated and actual (evidenced) effects of instructional media in classrooms and schools. Merely because curriculum producers are making software and their school customers are acquiring their products and the hardware to allow them to be used, does not tell us to what extent the daily lives of typical school children and their teachers are being affected or changed by these educational technologies (Becker, p. 20). Our need to visualize the roles and functions of educational technologies in classroom contexts has never been greater.

Early research on educational technologies (1970s and 1980s) emphasized the learning outcomes value-added model: the decontextualized, cognitive-psych pedigree of researching individual students' interactions with computers. Successive studies focused on the identification of mediating factors affecting the student-computer interaction. For example, meta-analyses of student learning studies suggested that computer-based instructional materials have a positive effect on student learning (C. Kulik and Kulik, 1991; J. A. Kulik, 1994) but indicated that the quality of the instructional design is critical to the instructional medium's effectiveness (Fletcher-Flinn and Gravatt, 1995). Researchers at the Center for Children and Technology noted that these early studies looked so specifically at particular technologies and their impact, they contributed little to the larger more challenging project of understanding the roles that technologies can play in addressing the key challenges of teaching and learning. In sum, these studies "tended to treat technology as a discrete, isolated, yet -it was hoped -overwhelmingly powerful input," in the classroom (McMillan Culp, Hawkins, and Honey, 1999, p. 2).

Recent research on educational technologies is characterized by an awareness that, in addition to the design of the instructional medium, local factors including the teacher's goals and current methods of instruction, implementation decisions made by educators, and the characteristics of the learners, profoundly affect the evolution of an educational technology in the classroom. Research by Coley et al. (1998) suggests that the effectiveness of an educational technology in any learning context is highly dependent on the complexities of the implementation process. Research and development of model educational technology programs in schools, while affirming our faith in the potential of educational technology to transform the teaching and learning environment, may tell us little about the complex interaction of particular factors which shape the implementation process. While exemplary programs showcase best practices for the use of educational technologies by teachers and students, they rarely describe the struggles of teachers and students to establish these best practices, within their local classroom and school environments. McMillan Culp et al.'s (1999) review paper on educational technology research and development suggests that the impact of technology on specific aspects of teaching and learning can be "usefully understood only in context" (p. 8). Technology alone does not translate into improved instructional outcomes. Technologies matter only when harnessed for particular ends in the social context of schools and classrooms, they must therefore be studied in these contexts.

The challenge of integrating technology into schools and classrooms is much more human than it is technological. "The teacher's role is of primary importance in creating an effective, technology-based learning environment- an environment that is characterized by careful planning and frequent interaction among students and the teacher" (Sivin-Kachala and Bialo, 2000, p. 11). The Web-Based Education Commission (2000) noted the critical role of the teacher in transforming educational technologies into useful tools:

> It is the teacher, after all, who guides instruction and shapes the instructional context in which the Internet and other technologies are used. It is a teacher's skill at this, more than any other factor, which determines the degree to which students learn from their Internet experiences. Teachers must be comfortable with technology, able to apply it appropriately, and conversant with new technological tools, resources and approaches. If all the pieces are put into place, teachers should find that they are empowered to advance their own professional skills through these tools as well. (p. 39)

How does the teacher adopt or adapt educational technologies to existing curricular contexts for learning? Cuban's (1986) discussion of the classroom use of technology since 1920 suggests that teachers can appropriate almost any kind of instructional material to their own goals and ways of teaching. A recent study conducted by the

National Center for Education Statistics (NCES) reported that when asked to focus specifically on the variety of potential uses of computers or the Internet in the classroom 33% of teachers reported feeling well or very well prepared, while 66% of teachers sampled stated they felt only somewhat prepared (53%) or not at all prepared (13%), to use these educational technologies (Rowand 2000). Yet our understanding of the process of how a teacher makes sense of novel pedagogic tools in the form of educational technologies is largely unexplored. How do educational technologies become part of a teacher's existing curriculum? Do the learning goals embedded in the educational technology match the teacher or school's local priorities and visions of quality education? Does the teacher experience a transformation in his or her role during the implementation of novel educational technologies in the classroom?

Schofield's (1997) review of research related to the impact of computer use on the affective and social dimensions of the classroom revealed that teachers' roles are influenced in a variety of unanticipated ways. The change in a teacher's role during the implementation of an educational technology is marked by a shift from whole group instruction to increased interaction with individual students or small groups of students, less emphasis on lecture, and more interactive, individualized, and student-centered activities (Becker, 1994b; Schofield, 1997; Penuel and Means, 1999). Kerr (1996b) noted that in some situations the advent of novel educational technologies has triggered a radical restructuring of classroom experience which also extends and elaborates the possibilities for student interaction. Sandholtz, Ringstaff and Dwyer's (1997) research with the Apple Classrooms of Tomorrow (ACOT) supports the belief that educational technologies can be a catalyst for educational change by "encouraging fundamentally different forms of interactions among students and between students and teachers" (p. 8). While attending to the perspective of the teacher, previous research concerning the evolution of teacher and student roles during the implementation of educational technologies in their classrooms tells us little about how *students* experience technology implementation over time.

Hammersley (1999) suggested that this general neglect of the way classroom contexts for learning are embedded in the lives of students can be attributed to "an exaggerated emphasis on the outputs of education at the expense of the process itself" (p. 1). Cuban (1993b) also noted the traditional absence of students' perspectives on classroom climate, teacher-student relationships, and the impact of (students') use of different instructional tools. While some studies have identified student attitude toward computer technologies as an important variable influencing their learning with new technologies (Francis & Evans, 1995; Liu, 1999; Christensen, 1997), these studies do not describe students' experiences with these educational technologies over time and in their own words. Instead, student reports have focused on the frequency of computer use in specific courses, the type of software utilized, and students' responses to an admittedly rough categorization of activities (Becker, 1994a). How do students' classroom experiences change with the introduction of novel learning tools? How do students perceive, or attribute meaning to their experiences with these educational technologies, over time?

Research Framework and Questions

Given these intersecting concerns for students, teachers, and factors influencing the human implementation process, the effects of educational technologies on teaching and learning can only be understood as part of multiple interacting factors in the complex life of classrooms. Various embedded contexts define the classroom workplace and shape the experiences of participants therein (McLaughlin & Talbert, 1990). This research focuses on four contexts. Schwab (1978) suggested that "defensible educational thought must take account of four commonplaces of equal rank: the learner, the teacher, the milieu, and the subject matter. None of these can be omitted without omitting a vital factor in educational thought and practice" (p. 371).

The present study uses Schwab's (1978) commonplaces to explore what happens in this curriculum quadrangle (teacher, students, subject matter, milieu) when change in subject matter "the scholarly materials under treatment" (p. 366) is initiated. This perturbation is represented by the implementation of an interactive learning system in two eighth grade math classes. Following Schwab, this study assumes that the contexts are constantly in interaction with one another. Therefore change in one curriculum context - namely subject matter, will perpetrate all curriculum contexts. Exploring the interactions among the four contexts enables us to begin to understand changes within the implementation process. Figure 1 presents all possible interactions among the curriculum contexts:

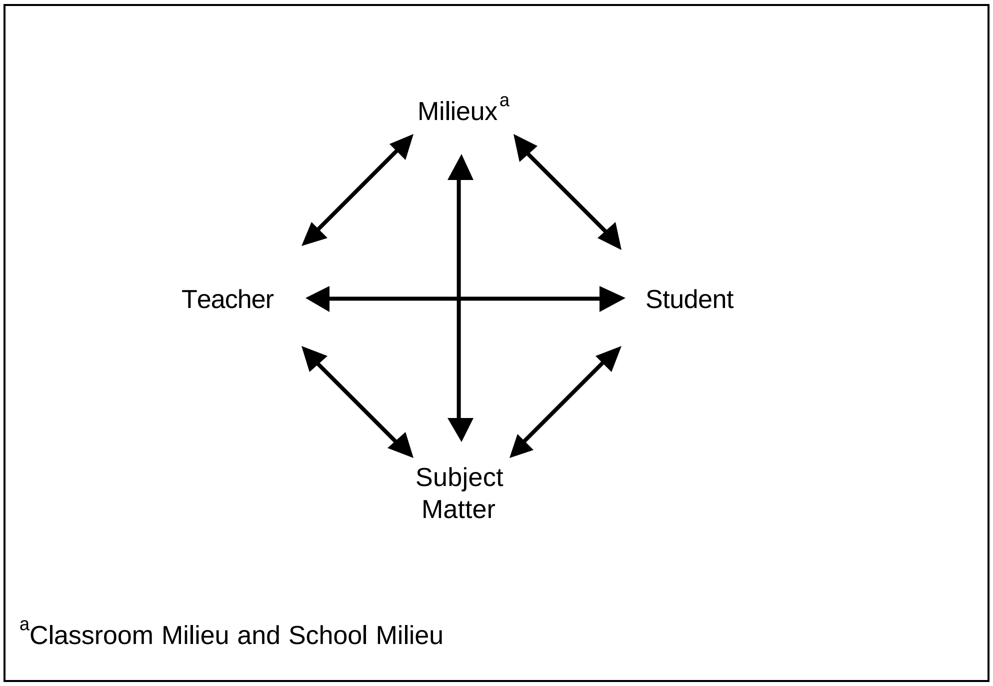

Figure 1. Curriculum Contexts: Teacher, Milieux, Student, Subject Matter

The point of departure for this study is the transition from the regular math class and the materials used therein to the computer lab and the use of an interactive learning system, Destination Math (DM), by students and their teacher. The intersection of curriculum contexts is explored prior to, and during, the implementation process. The primary research question focuses on this contextualized implementation of an educational technology:

> *How is an interactive learning system implemented in two eighth grade math classes, over time?*

As the commonplaces represent four *unified* points in the curriculum quadrangle, this study asks how students, teachers, subject matter, and milieu exist in relation with one another in the context of this change in subject matter. This study attempts to position the three commonplaces; teacher, student, milieu, in dialogue with this change in subject matter, and with one another, by asking:

> *What are the teacher's experiences of the educational technology, over time?*

> *What are the students' experiences of the educational technology, over time?*

The implementation process provides the *focus* for the current study. This research is concerned with how an interactive learning system is implemented over time. Two eighth grade math classes provide the *scope* for exploring this implementation process. Within each class there are different agents - an individual teacher and individual students. The teacher is perceived as a critical agent within the implementation process; decisions she makes prior to, and during, the implementation process, will directly affect her students' use of the interactive learning system. All participants within each class are perceived as active agents. Students and their teacher interact with the educational technology and with one another to perform different tasks. Schwab's four contexts provide a useful *framework* for exploring the actions of the teacher and her students within the research setting (Figure 1). Each action or interaction involving a teacher and or a student in the math class constitutes an *analytic unit* within the present research study. Each analytic unit can be further explored by asking, "What does the teacher or student do, say, or make within the math class?" Within this analytic unit, the school and classroom milieux afford certain *conditions* for participants' actions and interactions within the math class.

Research Context

The Local Context

Following Schwab (1978) the process of implementing a curriculum innovation or change must first be understood as local inquiry:

> The curriculum… will be brought to bear, not in some archetypical classroom, but in a particular locus in time and space with smells, shadows, seats, and conditions outside its walls, which may have much to do with what is achieved inside. Above all, the supposed beneficiary is not the generic child, not even a class or kind of child out of the psychological or sociological literature pertaining to the child. The beneficiary will consist of very local kinds of children, and within the local kinds, individual children. The same diversity holds with respect to teachers and what they do. (p. 310)

This study uses qualitative research methods to explore the process of implementing an interactive learning system in two lower level math classes in a rural mid-Atlantic

Junior–Senior High School over a fourteen-week period, in Spring 2001. During the first four weeks of this research, I visited students and their teacher in their regular math classes using the existing math curriculum. I refer to these first four weeks in the research setting as the pre-implementation stage. The process of implementing the interactive learning system continued during the following 10 weeks. For both eighth grade classes, the interactive learning system was implemented in the computer lab during their regularly scheduled (40 minute) math period on Wednesdays and on Thursdays. Students and their teacher used the existing math curriculum during the other three weekly math periods (Mondays, Tuesdays, Fridays). During this fourteen-week study, I visited each eighth grade math class on Wednesdays and Thursdays. Additionally, I frequently visited the regular math class on alternate days. Participants in this study included 32 students (14 and 18 in each class) and one classroom teacher. The informants' experiences of the implementation of the Riverdeep[1] (RVDP) Interactive Learning System in their mathematics class were the focus of this study.

The Riverdeep Interactive Learning System

RVDP was founded in Ireland in December 1995 as a developer and provider of technology-based educational solutions for the United States kindergarten through high school, or K-12 market. RVDP offers Internet and CD-ROM based comprehensive courseware and supplemental curricula in math, science, and language arts. RVDP Web-based and CD-ROM products have been installed in more than 45,000 schools in over 20

[1] Riverdeep learning resources for math can be previewed at the company web-site: http://www.riverdeep.net

countries worldwide and have won a number of awards for educational excellence and for contributions to the education of students.

Keenly interested in learning about RVDP's program of research and evaluation (having previewed RVDP educational materials on the company Web site), I initiated contact with RVDP personnel in February 2000. The design of this research project evolved from sustained conversations regarding my interest in exploring the implementation of novel educational technologies in a naturalistic setting. RVDP sales and marketing staff facilitated my search for, and identification of, a suitable research site. In Chapter 3, I further describe this process of gaining access to the research setting - two eighth grade math classes at Westridge Junior–Senior High School.

In November 2000, the Westridge school district purchased licenses for use of the RVDP interactive learning products by all eighth grade students and their teachers, intentionally targeting improvement of students' math skills. RVDP curriculum products for middle school math include:

- *Destination Math (DM):* A comprehensive math program designed to supplement or replace traditional math curricula.
- *Tangible Math (TM):* A simulation-based math program, which focuses on the development of problem solving and analytical skills.

Additional on-line resources for RVDP math programs incorporate correlations with state and national standards and popular textbooks, lesson plans, review and assessment activities, related educational web sites, and current and archived news items for teaching and learning math concepts. Subscribed RVDP users (teachers and students) have full access to RVDP's on-line resources.

In the present study, the teacher chose to implement the DM component of the RVDP suite of learning resources with both her eighth grade math classes. DM comprises five math courses organized in two series or curricula for students in grades four to twelve. The scope and sequence of the DM math content is presented in Appendix A. Participants in this study used DM Course IV: Mastering Skills and Concepts:

> This course focuses on arithmetic and the numbers and operations typically included in the middle school math curriculum. Each topic is presented within a motivational context that demonstrates how mathematical issues arise out of real-life situations. Within these contexts, students investigate properties of fractions, decimals, percents, and integers, and explore the rules that govern their operations. (Riverdeep, 2001)

This study explored the experiences of students and their teacher in two eighth grade math classes (of basic skills and concepts) over a fourteen-week period, during the pre-implementation (4 weeks) and implementation (10 weeks) of the DM interactive learning system.

Definitions

Educational Technology: Of the many definitions of technology and educational technology (Gentry, 1995), this study uses Ely's (1999a) definition of technology as "the equipment that delivers text, moving images, graphics and the like." This equipment takes the form of a variety of computer-based systems. "Educational technologies are not single technologies but complex combinations of hardware and software" (Means et al. (1993, chap. 2, para. 1). Educational technology is defined as the use of these computer-based, networked learning systems to satisfy educational objectives. Educational technology also represents a novel form of instructional media -one which facilitates increased student-interaction with subject matter.

Experience: Following Dewey (1938), experience is understood to have depth and exist *in* and *of* nature. Some experiences may be stable while others may fluctuate in resonance with the individual's interaction with his or her environment. In the present study, use of the term *experience* incorporates both what the individual thinks about the interactive learning system (portrayed in his or her language) and how the individual uses the interactive learning system (demonstrated by his or her activity) over time.

Implementation: Implementation occurs when an individual puts an innovation to use (Rogers, 1995). In this dissertation study, the interactive learning system is utilized by students and their teacher over a ten-week period, during their regularly scheduled math class on Wednesdays and Thursdays.

Innovation: Rogers (1995) defined an innovation as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (p. 11). In the present study, the interactive learning system, DM, represents a curriculum innovation in two eighth grade math classes.

Instructional Media: Reiser and Gagne (1983) define instructional media as the physical means by which instruction is presented to learners. Using this definition, the phrase *instructional media*, would refer to every physical means of delivering instruction to the learner. To facilitate the present discussion of the evolution of instructional media, following Reiser (2001), the term instructional media is used to refer to "the physical means, other than the teacher, chalkboard, and textbook, via which instruction is presented to learners" (p. 55).

Interactive Learning System: Interactivity has been defined as the exchange of ideas and thoughts that build on previous statements within a given context (Rafaeli, 1988). In the present study, an interactive learning system is defined as one in which student actions elicit computer responses that promote interpretation and reflection and give students greater opportunities to control their own learning.

Students: According to Schwab (1978), learners are the "children who are to be the beneficiaries of the curricular operation" (p. 366). In this study, the learners are 32 students in two eighth grade math classes.

Milieu: Following Schwab (1978), milieux (plural) represent the places "the child's learning will take place and in which its fruits will be brought to bear" (p. 366). Schwab explains that the relevant milieux are manifold. This research study takes place within the classroom milieu. Due consideration is given to the school milieu in accordance with the extent to which it influences what happens in the classroom teaching-learning environment.

Subject Matter: Schwab (1978) described subject matter as "the scholarly materials under treatment and … the discipline from which they come" (p.366). In the present study, the eighth grade mathematics course in Basic Skills and Concepts (fractions, decimals, integers and order of operations), and the RVDP Interactive Learning System, DM, respectively constitute the discipline and materials in question.

Teacher: In this dissertation, the teacher is the certified educator of the eighth grade math students.

Time: The phrase *over time* as it is used in this study, refers to the fourteen-week exploration of the initial implementation of the RVDP interactive learning system in the research setting. The first four weeks of this study are referred to as the *pre-implementation* stage of research. The *implementation* stage continued during the following 10 weeks. For both eighth grade classes, the interactive learning system was implemented in the computer lab during their regularly scheduled (40 minute) math period twice weekly (on Wednesdays and on Thursdays).

Purpose of this Study

This study does not begin with a detailed description of the capabilities of an interactive learning system, but rather with the experiences of one teacher and her eighth grade students in their regular math classes. In its broadest terms, this research asks what a technological innovation (in the form of an interactive learning system) *looks like* from the informed perspective of this teacher and her students. The purpose of this study is to describe the experiences of one teacher and her students with an interactive learning system over time. The main research question asks: How is an interactive learning system implemented in two eighth grade math classes, over time? Four curriculum contexts (teachers, students, milieu, subject matter) frame this research question and focus the discussion on the relationship between the subject matter (an eighth grade math course in mastering skills and concepts, and the DM learning resources) and the teacher, students and milieux for learning. Supporting research questions ask: What is the teacher's experience of the interactive learning system over time? What are the students' experiences of the interactive learning system over time? These questions will be answerable by asking the more informal question: What do participants do, say and make in the research context over time?

Significance of this Study

Rossman and Rallis (1998) insist that the purpose of research is to generate useful knowledge: "your goal is to communicate so that others may use what you have discovered" (p.203). Given the prevalence of model studies -those studies which document exemplary use of educational technologies, this qualitative research study attempts to help bridge the chasm between demonstrations of prototype innovations and our understanding of an actual classroom implementation of an educational technology (McMillan Culp et al., 1999). Stated in broad terms, the goal of this study is to enliven and enlighten our discussion of how technology implementation is mediated by embedded contexts for learning including the teacher, students, existing subject matter, and classroom and school milieux. Understanding what a technological innovation is used for, how it is used, what the users think of it, and how they evaluate or assess it, enables us to slowly begin to answer the larger, more elusive, and particularly crude question, "Does it work?" The value of this research is premised on the understanding that the effectiveness of technology will vary as a function of the contexts in which it is embedded. A detailed description of why users adopt, adapt, or reject a particular technological innovation will enable us to begin to map the implementation process in much greater detail, and understand how to support teachers and students in their implementation of educational technologies. This research will also increase our understanding of how the initial excitement of new resources and new ideas can be translated into sustained commitments to new forms of teaching and learning with educational technologies. Implications for staff development activities, professional practice, and curriculum design, are anticipated. Hativa and Lesgold (1996) note that "basing the instructional design of computer applications solely on design theories developed for non-technological settings is not enough" (p. 167). Instructional designers can also benefit from contextualized research of learning technologies.

CHAPTER 2

OVERVIEW OF THE LITERATURE

> School improvement, like motherhood has many advocates. Everyone is for it, without having to campaign actively on its behalf. And just as the 100% of people who have had mothers think they know how mothering could be done better, so the (nearly) 100% of people who have been pupils in schools, or have even taught in or managed them, think they know how schools can be improved. (Huberman, 1984, p. v)

Researchers, developers, and educators have been seeking to define the best roles and functions for educational technologies since computers began appearing in schools in the mid-1960s (Cuban, 1986). Almost four decades later research on the implementation of educational technologies in the classroom has yielded an ambiguous record regarding their effectiveness. This chapter explicates the need for context-based research of educational technologies by first exploring the shifting focus of past research efforts and the lessons learned from each new research orientation. A review of the implementation process is presented, and conditions affecting the implementation of educational technologies are explored. While we generally identify teaching and learning as the fundamental processes of schooling, these processes are embedded within dynamic contexts (teacher, student, subject matter, milieux) and thus subject to change. My discussion focuses on descriptions of how educational technologies may change teachers' instructional practices and students' experiences in classrooms. The chapter concludes with a call for representation of students' voices within the current research of educational technology effectiveness in schools.

Trends in Research and Discussion of Educational Technologies

The argument supporting implementation and integration of educational technologies in schools is hampered by the lack of consistent evidence regarding the benefits of teacher and student use of educational technologies. This absence has fueled a backlash against technology in the popular press (Johnson, 1998). Critics question the sagacity –the very utility, of implementing novel educational technologies in classrooms. In 1990, Postman cautioned that even a brief study of the history of technology reveals that technological change is always a Faustian bargain: "Technology giveth and technology taketh away, and not always in equal measure" (p. 1). A persistent critic of society's unbridled fascination with technology, Postman (1992) introduced the phrase "Technopoly," to refer to the deification of technology by members of a culture who seek authorization and satisfaction from the technology itself. Focusing his critique on the implementation of educational technologies in schools, Apple (1991) argued that the more an educational technology transforms the classroom into its own image "the more a technical logic will replace critical political and ethical understanding" (p. 75). Oppenheimer (1997) lamented this triumph of technical logic within our schools claiming, "There is no good evidence that most uses of computers significantly improve teaching and learning, yet school districts are cutting programs … that enrich children's lives to make room for this dubious nostrum"(p. 1).

Student Outcomes

Early research on educational technologies in schools focused on identifying learning outcomes of individual students working directly with machines. For example, Kulik's (1994) meta-analytic study of (primarily drill and practice) computer-based instructional software developed prior to 1991 identified various student gains including increased learning, more efficient learning, increased motivation, and the development of positive attitudes toward the use of computers. More recent studies of the effects of computer-assisted instruction (CAI) on student learning associated student benefits with certain *features* or affordances (Gibson, 1977; Pea 1993; CTGV, 1993)[2] of educational technologies. Mills (1994) found that Integrated Learning Systems (ILS) facilitated integration of academic skills, remediation, and enrichment opportunities with school curricula by offering students individualized instruction tailored to their own needs and proclivities. However, in their meta-analysis of 120 CAI studies, Fletcher-Flinn and Gravatt (1995) found no significant differences between educational outcomes achieved with students who used CAI and the regular control groups. They concluded that the quality of the instructional design of a technology-enhanced learning environment is critical to its effectiveness in improving students' learning outcomes. These early studies looked so specifically at particular technologies and their impact on the individual learner that they contribute little to our understanding of how educational technologies take shape in realistic contexts: within local classrooms, with real teachers and students, existing curricula, and indigenous school cultures.

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[2] Gibson's (1977) notion of affordances suggests that features of the environment enable specific activities for particular organisms. Pea (1993) described affordances as perceived and actual properties of a thing, specifically "those functional properties that determine just how the thing could possibly be used" (p.51). The Cognition and Technology Group at Vanderbilt (CTGV, 1993) used the notion of affordances to clarify design principles (that grounded their choice and development of anchors in the Jasper Series) and relate these design principles to teacher and student learning processes. The CTGV cautioned that although affordances make various activities possible with educational technologies, they do not guarantee them.

Teacher's Instructional Objectives

Researchers at the Educational Testing Service (ETS) noted that while rudimentary uses of educational technologies in schools (e.g., CAI or ILS to attain specific student outcomes) appear to be effective and efficient, more contextualized and pedagogically complex uses of educational technologies often show inconclusive results (Coley et al, 1998). For example, Wood's (1991) research of the effects of math achievement of two different types of software -tutorial and tool programs, revealed that the students who used the tutorial system gained in computational skills, while the students who used the tool system gained in their understanding of algebraic concepts. Wood's findings suggest that the most successful or effective use of educational technologies is dependent on the match between the particular instructional objectives and methods of the teacher and the specific affordances of the technological innovation. The Web-Based Education Commission (2000) found that teachers often used technology to mimic the pattern of a top-down lecture or text driven model of instruction, despite the fact that technology can support what we know to be better learning environments. Similarly, Means and Olson (1995) noted that many instructional uses of technology merely reinforced traditional, didactic modes of instruction, which were promulgated by existing school regimes and philosophies.

Goals of Schools

To re-focus this debate regarding the justification for implementing educational technologies in schools, Postman (1995) called for a reassessment of the real purpose of schools. Similarly, Cuban (2000a, para.21) argued that any school community needs to first reach a concensus regarding its own goals and purposes for educating students and "then ask, 'Now how might the technology help us reach these goals?'" Concentrating this discussion *within schools* and not on educational technologies, or the market place that breeds them, enables us to be concerned with how a student might make a life as opposed to how he or she might make a living (Postman, 1995). Educational goals espoused by teachers and administrators within schools and classrooms are often poorly matched with learning goals embedded in the educational technologies being implemented in these contexts. Indeed, proponents of transformative educational technologies frequently attribute blame for failed applications of educational technology in schools (not to the technologies themselves or to those who implement them, but rather) to the disparity between what the technology affords, and the traditional and outdated institutionalized system of schooling and classroom instruction (Perelman, 1992; Lemke, 1993; Schank and Cleary, 1995; Papert, 1998a). The present research study seeks to establish the relationship between both the teacher's current instructional practices and those embedded in, or afforded by, an interactive learning system by asking how these instructional methods relate within the conditions which create and sustain a particular classroom milieu.

Classroom Cultures

Inevitably, the implementation of a given educational technology is subject to the attributes of the classroom milieu in which it is put into practice. The power of existing cultural patterns of interaction within classrooms may profoundly shape how an educational technology is implemented. Kerr (1996a) noted that "the very reasons a technology is adopted in the first place -are often radically different from the ways in which a technology actually comes to be used [within the classroom]" (p. 149). Because computers are social as well as technological objects, their use is subject to the vagaries of the social milieu in which they are available for use, although over time they may profoundly influence that milieu (Schofield, 1995). Papert (1992) suggested that educational technologies are usually introduced in classrooms to achieve specific educational objectives, and their "first-order effects" (p. 53) are measured by assessing the extent to which these objectives are achieved. Papert added that upon entering the culture of the school and classroom, the innovation can weave itself into learning in many more ways than its original promoters could possibly have anticipated. These contextual effects of the use of educational technologies in classrooms are referred to as the "second-order effects or systemic effects of the computer presence" (Papert, p. 53). Similarly, Hativa and Lesgold (1996) explained that "the actual results of students' interactions with a learning environment may be much different from those planned for and expected by the designers of the environment" (p. 164); the way we typically use computer technologies may define and limit, as well as extend and redefine, student and teacher interactions.

This research study is premised on the assumption that the implementation of educational technologies in schools can be best understood by exploring the multiple interacting contexts which shape the lives of classrooms. By entering into the complicated intersections of students, teachers, and classroom and school milieux, and by perceiving an educational technology as an object for change in subject matter, we can deepen our understanding of the process of implementing educational technologies within classrooms. By focusing on the experiences of one teacher and her students in two eighth grade math classes, this study seeks to enliven and enlighten our understanding of how an educational technology *shapes*, and *takes shape* in particular classroom contexts.

The Implementation Process

A process approach (one which is sensitive to changes over time) within the present study facilitates exploration of the changes in relationship between these contexts during the implementation of an educational technology. At a macro (school) level, Cuban (1986) has postulated that the new technologies progress through a series of implementation stages within schools; utopian expectations at first lead to massive funding, but disappointment with results then leads to *teacher-bashing* – blaming teachers for being afraid, unwilling, or just unable to use the technology. The level of use then sinks to a minimum and is only revived through a fixation on some new technology or application as a solution. Then the implementation process begins again. Based on his review of national assessments and statistics on the implementation of educational technologies in classrooms, Cuban (2000b) presents the following synopsis:

> The facts are clear. Two decades after the introduction of personal computers in the nation, with more and more schools being wired, and abundant dollars being spent, less than two of every ten teachers are serious users of computers in their classrooms (several times a week). Three to four are occasional users (about once a month). The rest – four to five teachers of every ten teachers – never use the machines. When the type of use is examined, these powerful technologies end up being used most often for word processing and low-end applications in classrooms that maintain rather than alter existing teaching practices. After billions of dollars have increased access to computers, the Internet and software in the last decade, after corporate executives, academics and public officials have promised technologically-inspired reforms that would revolutionize teaching and learning- the results are, indeed, meager. (p. 46)

Cuban's analysis of the cycle of implementing novel educational technologies in schools, while particularly scathing, reminds us how little we know about the human process of implementing educational innovations within classrooms. Table 1 presents three models of the human implementation process. I identify stages for each of the three models presented. Rogers' (1995) stages in the implementation of innovations are listed in the second column of Table1, entitled *Change*. Founded on theories of sociology, psychology, and communications, Rogers' discussion of the diffusion of innovations is based on his comprehensive review and synthesis of diffusion publications and case examples of technology transfer. The third column in Table 1, entitled *Educational Change*, lists the three broad phases in Fullan's (1991) depiction of the educational change process. Fullan contends that real change in schools is difficult to accomplish and can only occur under certain circumstances. Sandholz, Ringstaff and Dwyer's (1997) model of instructional change, based on a decade of research with the Apple Classrooms of Tomorrow (ACOT), describes the process of instructional change during the classroom implementation of an educational technology. Stages in Sandholz et al.'s model are represented in the fourth column of Table 1, entitled *Instructional Change*. The summary of change models presented in Table 1, is not intended to simplify the dynamic change process. As Fullan (1991) cautioned, such a figure merely provides a "general image of a much more detailed and snarled process" (p.48). Understanding any complex change process involves seeing the interrelationships between the stages outlined in Table 1 and seeing beyond these snapshots to the richly detailed processes of change which characterize a particular change story (Fullan, 1997).

Table 1

The Human Implementation Process

Stage	Change[a]	Educational Change[b]	Instructional Change[c]
1[d]	Knowledge Persuasion Decision	Initiation	Entry
2[e]	Implementation	Implementation	Adoption Adaptation Appropriation Invention
3[f]	Confirmation	Continuation Outcome	

Note. [a]Rogers (1995) presents a systematic, linear model of the innovation-decision process. [b]Fullan (1991) identifies four broad, overlapping stages in the change process. [c]Sandholtz et al. (1997) describe five consecutive stages in their model of instructional evolution in technology-enhanced classrooms.

[d]Pre-Implementation Stage, [e]Implementation Stage, [f]Implementation Outcome

Stage 1: Pre-Implementation

Rogers (1995) provided a detailed description of the diffusion of an innovation -the process by which a new idea or practice may be adopted. He suggested three types of *knowledge* about an innovation which are likely to affect the decision an individual makes to adopt or reject an innovation:

1. Awareness knowledge: Information that an innovation exists
2. How-to-knowledge: Information necessary to use an innovation properly

3. Principles knowledge: Information dealing with the functioning principles underlying how the innovation works

For Rogers (1995), the next phase in the innovation adoption process occurs when an individual forms a favorable or unfavorable attitude toward the innovation. This is described as *persuasion*. Here an individual (e.g., teacher) who is presented with an innovation (e.g., interactive learning system) seeks answers to questions concerning the proposed implementation: What are the innovation's consequences? What will it's advantages and disadvantages be in my situation? The individual's *decision* to adopt or reject the innovation is evident in his or her engagement in activities that demonstrate support for, or rejection of, the particular innovation.

The first stage in Sandholz et al's (1997) model of instructional change, called *entry*, is characterized by teachers' "trepidation and excitement" (p. 37). During this pre-implementation stage, teachers re-evaluate or even regret their decision to tolerate change. Preparations for implementation are evident in the change of the teacher's physical environment, with the arrival of components of the educational technology.

Fullan (1991) identified five factors which are likely to affect this first stage in the change process for an individual teacher:

1. existence and quality of innovations
2. access to innovations
3. advocacy from central administration
4. teacher advocacy
5. external change agents

Fullan also noted that the question of who initiates the educational change (teacher, administrator, external agent) will profoundly influence the implementation outcome.

In the present study, a detailed portrayal of this pre-implementation stage -including the factors which influence the teacher's decision to adopt the interactive learning system, enables us to begin to understand the teacher and her students' initial experiences of the educational technology. The first four weeks of this study are therefore referred to as the pre-implementation stage of research. This study is premised on the notion that understanding the participants' expectations for change, and the conditions which influence their decisions to implement change, is essential if we are to begin to explore the larger implementation process. "What happens at one stage of the change process strongly affects subsequent stages" (Fullan, p. 49).

<u>Stage 2: Implementation</u>

Implementation occurs when an individual (e.g., teacher or student) puts an innovation to use (Rogers, 1995). Sandholz et al. (1997) referred to this process of utilizing an educational technology innovation, as *adoption*. For ACOT teachers who were using technology innovations for the first time, this stage was characterized by an increasing interest and concern for integrating the technology into their regular instruction. During the next phase in the implementation stage, *adaptation*, Sandholz et al. noted that "the new technology became thoroughly integrated into traditional classroom practice" (p. 41). Lecture, recitation, and seatwork remained the dominant instructional methods, although students used computers more and more frequently. ACOT teachers' increasingly positive attitudes towards the technologies they deployed in their classrooms marked their arrival at the third implementation phase, *appropriation*.

Re-invention may occur at any time during these implementation phases (Rogers, 1995). Rogers described reinvention as the degree to which an innovation is changed or modified by a user in the process of its adoption and implementation. He asserted that for many innovations and adopters, at least some degree of re-invention occurs at the implementation stage. Rogers claimed that adopters generally think that re-invention is desirable. Sandholz et al (1997) referred to this phenomenon as *invention*. They noted that "in the invention stage, teachers experimented with new instructional patterns and ways of relating to students and to other teachers" (p. 44)

While the notion of implementation (including the factors affecting a teacher's actual use of an innovation) "has proven to be exceedingly elusive," Fullan (1991, p. 66) suggested that the *fit* between an individual's need for change and what the proposed change offers, will indeed affect the individual (e.g., teacher)'s implementation of an innovation. Additionally, Fullan proposed that additional factors including the clarity of the individual's articulated goals and needs, the quality and practicality of the innovation for the individual, and the complexity of the change required of the individual, also affect the human implementation process.

Stage 3: Implementation Outcome

Although Sandholz et al's (1997) model for instructional change during the implementation of educational technologies does not specify a post-implementation or participant evaluation stage, the researchers suggested that teachers' *continued use* of technology was the outcome of three notably positive changes concerning the instructional enterprise:

- Teachers' beliefs about the instructional activity (evident in their willingness to experiment)
- Shifts in teacher and student roles (evident in more student-centered instruction)
- Shifts in relationships among teaching colleagues (evident in team teaching)

Rogers (1995) explained that individuals (e.g., teachers) may seek *confirmation* or reinforcement of the innovation-decisions they previously made; if exposed to conflicting messages about the innovation, individuals may reverse an earlier decision to adopt or reject the innovation. For example, an individual may discontinue implementation of an innovation because of his or her disenchantment or dissatisfaction with it, or simply because a newer, better innovation has entered the picture. Fullan (1991) also described the positive and negative implications of the *continuation* decision users make. He suggested that continuation (institutionalization of innovations) depends on whether or not the change:

- Becomes embedded or built into the current structure (e.g. through policy, budget, or timetable)[3]
- Has generated a critical mass of administrators or teachers who are skilled and committed to change
- Has established procedures for continuing assistance (Huberman & Miles 1984)

Fullan (1991) suggested that in the final analysis, the actual *outcome* of the change process may depend on factors which are difficult to predict prior to the implementation of the innovation. Each set of factors is represented as a dualism as follows:

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[3] If sufficiently flexible, an educational technology innovation may be adapted to existing school structures and teaching styles -if not, it may simply be ignored (Cohen, 1987; Cuban 1986).

1. active versus inactive initiation and participation in the innovation-change process
2. pressure versus support during the process
3. change versus no change in behavior and beliefs
4. ownership versus no ownership of the change process

The actions of the innovating individual (e.g., teacher) are central to Fullan's implementation process, but they must be visualized within the broader context which enables them. "These individuals are insignificant parts of a gigantic, loosely organized, complex, messy social system" (p. 92).

Within the present study, Schwab's four loci (teacher, students, subject matter, milieu) enable us to examine the human implementation of an educational technology by situating the teacher and her students within the social systems afforded by their local classroom and school milieux. Information gathered during the pre-implementation stage provides a vital preface to the story of this ten-week initial implementation of novel subject matter for math (in the form of the RVDP interactive learning system) in two eighth grade classes. Participants' perspectives of the implementation outcome are explored during the final weeks of this study. Explication of students' and their teacher's implementation experiences with the interactive learning system during the implementation and implementation outcome stages, enables us to trace the contextualized evolution of this particular educational technology over time. What is the *fit* between the participants' expectations for change and their perceptions of what the interactive learning system actually offers them? How do participants' experiences with the interactive learning system change over time? How do the interactions among the curriculum contexts (teacher, students, subject matter, milieu) affect the teacher's position vis-à-vis Sandholz et al.'s (1997) stages of instructional change?

Conditions Supporting the Implementation of Educational Technologies

The challenge of integrating technology into schools and classrooms is much more human that it is technological. It is not fundamentally about helping people to operate machines, it is about enabling teachers to integrate these educational technologies into their teaching, as tools of their profession (Means et al, 1993). What factors support or impede the decisions a teacher makes to implement an educational technology? Based on his research of successful implementation of educational technologies in various contexts, Ely (1976, 1990) established a set of conditions which support the educational technology implementation process. Ely's eight reasons for successful change efforts are listed in the second column of Table 2. Becker's (1994b) analysis of teacher use of novel educational technologies also focused on conditions which facilitated or supported the implementation process. The four primary factors that Becker identified as contributing positively to a teacher's implementation of educational technologies, are listed in the third column of Table 2. To facilitate the present discussion, each condition listed in Table 2 is described as primarily pertaining to the teacher or the local conditions for his or her technology implementation (Table 2, Column 1). This is not to assume that a condition for implementation cannot be described as both internal and external to the teacher, but rather to underline the importance of remaining aware of the complexities of the interaction between teacher and local factors in the implementation process.

Table 2

Conditions which Facilitate the Implementation of Educational Technology Innovations

Stage	Ely (1976, 1990)	Becker (1994b)
Teacher Factors	Dissatisfaction with the status quo Knowledge and Skills Time Participation	Sustained Use of Computers Network of Supporting Colleagues
Local Factors	Resources Rewards or Incentives Commitment Leadership	Awareness & Support of Resource Requirements Organized Support

Teacher Factors

Ely (1999b, para. 13) suggested that an individual's innate or induced *dissatisfaction with the status quo* "is an emotion that calls for change," and supports the implementation of an educational technology. In his research of teachers' lives and careers, Huberman (1993) also noted that teachers who desired educational innovation and reform expressed a strong need "to renew themselves… with new pedagogical experiments" (p. 164).

Knowledge of, and experience with, an educational technology may also support an individual's decision to implement (Ely, 1976, 1990). "Implementers need time to acquire knowledge and skills, plan for use, adapt, integrate and reflect upon what they are doing" (Ely, 1999b). A significant internal factor characterizing Becker's (1994b) exemplary computer-using teachers was their prior experience with, and knowledge of, technology over *time*. These teachers spent more than twice as many hours as other computer-using teachers, personally working on computers at school. Exemplary computer-using teachers also demonstrated *sustained use of computers* within their school environment (Becker, 1994b). Honey et al. (1995) also found that successful implementation was related to teachers' prior and continued experience with educational technology. In their survey of approximately 1,200 educational professionals, Norris, Topp and Soloway found that "teachers with more technology experience, as indicated by the use of email at home for example, appeared more comfortable with technology in the classroom than those who reported low email use at home" (Soloway et al., 2000, p. 26).

Becker's (1994b) exemplary computer-using teachers also cited their collegiality, or participation in a *social network of computer-using teachers* within the school as a significant factor influencing their use of educational technologies. In a later study, Becker (2000c) noted that successful computer-using teachers "orient toward collaboration with each other and toward taking a leadership role in their profession" (p. 54). Ely (1976, 1990) also suggested that *participation* (shared decision-making) in the implementation process is an important condition supporting any change effort involving educational technology innovations.

Local Factors

A number of local (classroom, school, school district) factors may also support the implementation of an educational technology. "The evidence suggests that it is necessary to focus attention on providing a supportive environment for class-related use, as opposed to developing teacher attitudes and skills independent of broader curricular… issues" (Ravitz, 1997, p. iii-iv). Becker (1994b) found that exemplary computer-using teachers taught in schools where there was *awareness and support of the resource requirements* teachers needed to effectively implement educational technologies in their classrooms. "This condition [*availability of resources*] refers to the things that are required to make implementation work. It includes hardware, software, publications, audiovisual media and other teaching materials" (Ely, 1999b, para. 15).

Ely (1976, 1990, 1999b) described three additional types of organizational support for the implementation of an educational technology: *extrinsic rewards or incentives*, *commitment* (continuing support) for the implementation of the innovation, and strong, supportive *leadership* within the organization (e.g., school, innovation team). Similarly, Becker (1994b) identified elements of *organized support* which influenced a teacher's ability to demonstrate exemplary uses of educational technologies, within his or her class. These organized supports included professional development, assistance from a residential computer coordinator and leadership support.

Professional development has emerged as one of the most critical conditions supporting the implementation of educational technologies in schools. Capper (2000) noted that inadequate training and support of teachers has consistently been identified as the single-most problematic issue in introducing technology into classrooms in developed countries. The Web-Based Educational Commission (2000) called for professional development to enable teachers apply their current skills with educational technologies to classroom instruction. Similarly, researchers with the National Center for Education Statistics (NCES) found that teachers who spent more time in professional development activities were generally more likely than teachers who spent less time in such activities to indicate they felt *well prepared* or *very well prepared* to use computers and the Internet for instruction (Smerdon et al., 2000). NCES researchers also found that 82% of teachers surveyed ranked *lack of release time* as the greatest impediment to their use of computers in the classroom. Lack of time for staff development, was perceived by teachers as a barrier to learning, practicing or planning ways to use educational technologies (Smerdon et al., 2000).

In addition to teacher and local factors discussed in Table 2, Fullan (1991) suggested that external factors also influence implementation decisions made by teachers. “The last set of factors that influence implementation places the school district in the context of the broader society” (p. 78-79). For example, implementation decisions a teacher makes may be affected by provincial, state or national priorities or mandates for education.

In the present study, explication of teacher, local, and external factors affecting the implementation of an educational technology in two eighth grade classes, continues through the pre-implementation, implementation, and implementation outcome stages of this research thereby extending our understanding of the human process of implementing an educational technology. Fluctuations or changes in the level at which these conditions support or impede implementation decisions made by the teacher, are assumed over time. It is important therefore to trace the teacher’s discussion of these conditions, through the fourteen week implementation process. The present study asks how the teacher describes conditions which influence her twice-weekly implementation of the interactive learning system in her two eighth grade math classes, during one school semester.

Change in Teacher's Instructional Model

Local factors including the availability of educational technology resources may affect the frequency and structure of how a teacher chooses to implement an educational technology for instruction. For example, Becker (1994a) noted that the location of educational technology resources within a teacher's classroom (as opposed to a dedicated computer lab) significantly facilitated the teacher's efforts to seamlessly integrate computer activities with other learning activities during a varied instructional day or period. Becker explained that while the typical lab has 21 computers and the typical classroom has only two, the problem with having computers sequestered in labs is that teachers don't appear to use them for instructional purposes as frequently (Soloway, et al., 2000). In their short survey of public school teachers in 1999, researchers with the National Center for Education Statistics (NCES) found that "teachers were generally more likely to use computers and the Internet when located in their classrooms than elsewhere in the school, while their students were more likely to use computers and the Internet outside the classroom than inside" (Smerdon et al., 2000). Of the 4,083 fourth to twelfth grade teachers sampled in Becker's Teaching, Learning and Computing (TLC) study in 1994, researchers found that teachers with just five or six classroom computers were more likely to use them for regular instruction than teachers with access to computer labs containing substantially more computers (Soloway et al., 2000). Table 3 presents percentages of teachers who gave students a "reasonably frequent opportunity to use computers - more than 20 occasions during most of a year" (p. 25):

Table 3

Teachers who Gave Students a Frequent Opportunity[a] to Use Computers

Classroom (5+ Computers)	Classroom (1-4 Computers)	Computer Lab (15+ computers)
62%	32%	18%

Note. Source: (Soloway et al., 2000, p.25)

[a] Frequent Opportunity is defined as more than twenty occasions during a school year

Becker (1998a) also suggested that locating educational technologies in teachers' classrooms facilitated "using technology in ways that are specifically chosen for their contribution in making major changes to the culture of classrooms" (Becker, p.26). Given supportive conditions for the implementation of educational technologies in their classes, Cuban (1997) noted that teachers' instructional changes - while not as immediate as we might anticipate or expect, were indeed significant over time. Reflecting on the results of the ACOT researchers' three-year study of technology implementation in classrooms, Cuban explained:

> The researchers watched what happened, listened to teachers, and documented small, incremental, but significant changes in classroom practices. They recorded how classrooms became places of traditional and nontraditional teaching, imaginative hybrids of practice that emerged over time. (p. xiii)

In his study of teachers' self-reported instructional practices using educational technologies, Becker (1998b) found a variety of significant differences between the instructional models of teachers who had used computers at least weekly for three or more years and teachers whose students seldom or never used computers in their classes.

There was a clear pattern of instructional change related to *long-term* computer use with students. Long-term computer and Internet-using teachers were:

- More willing to discuss subject about which they lacked expertise
- Allowing themselves to be taught by students
- Orchestrating multiple simultaneous activities in the classroom at the same time
- Defining long and complex projects for students to undertake
- Giving students greater choice in tasks and materials and resources to be used to conduct them

Penuel and Means (1999) also noted changes with respect to the role of the teacher over time. In their study of computer-using and non-computer-using classes, they found far fewer technology-using teachers used questioning as their dominant way of relating to students (7% in technology classrooms compared with 29% in non-technology classrooms). The researchers also found that technology-using teachers were much more likely to be in a helping or monitoring role in the classroom (Penuel and Means, 1999). Similarly, in their analysis of the *Challenge 2000: Multimedia Project*, researchers at SRI International's Center for Technology and Learning noted significant differences between the teacher's role in dominant activities observed in technology-using classes, compared with non-technology-using classes. In the comparison classrooms, students were likely to be engaged in *teacher directed solo activities* while in the technology-using classes students were just as likely to be engaged in higher-level cognitive activities.

Becker (1998b) suggested that these activities could be interpreted as efforts on behalf of teachers to use the technology to *let go* and begin to cede some classroom authority to students. Indeed, educational technologies provide so much more information in so many different ways to users that a teacher can no longer expect to know or control the precise flow of information to the learner (Boethel & Dimrock, 1999). Meyrowitz (1996) cautioned that these educational technologies in and of themselves are "not as central to tomorrow's schooling as are new roles for the teacher and student, which the technology makes possible" (p. 101).

In the present research study guiding questions ask: How does the location of educational technologies affect the frequency and activity structure of teacher and student use of the interactive learning system in the eighth grade math class? Does a pattern of teacher instructional change evolve during the fourteen-week implementation of the RVDP educational technology? How are students' and their teacher's roles defined and redefined during this implementation process?

Change in Students' Classroom Experience

In most conventional teaching-learning contexts, learners have limited control over what (or how) they are taught. "Learners often try to adjust their thinking to comply with perceived expectations of others such as teachers" (McCaslin & Good, 1992). While educational technologies generally enable students to exercise increased choice and control of their own classroom learning, students' experiences of educational technology in schools remain bound to their teacher's implementation of the innovation. For example, of the six factors Becker (2000b) identifies as important in affecting a student's experience of educational technology in schools, four (no. 2-5) are determined by the student's teacher:

1. availability of computers in the classroom
2. teacher computer expertise

3. teacher philosophy and objectives for computer use
4. teacher collaboration and leadership
5. teacher judgments of class ability
6. school SES level

The choices teachers make during their implementation of educational technologies directly affect their students' experiences with these instructional tools. In his analysis of national tests and questionnaires to research student use of educational technologies in mathematics, Becker (2000c) found that despite the availability of hardware and software in students' classes, "using general-purpose computers for more sophisticated applications – such as spreadsheet calculations, analysis of large amounts of real data, or library research into real-word applications of quantitative procedures – has not yet become part of the curricula in most middle and high school mathematics classrooms." (p. 50). In his research on students' use of educational technologies in schools, Wenglinsky (1998) also reported that the greatest inequities did not lie in how often educational technologies were used by students, but rather how the teacher chose to use them with students -for example, to develop lower or higher order thinking skills.

Research supports students' continued use of educational technologies in schools to increase their interest in learning; improved academic performance and increased student motivation and student satisfaction have been identified as benefits of student learning in technologically enhanced learning environments (Means & Olsen, 1995; Schank & Cleary, 1995; Glennan & Melmed, 1996; Sandholtz et al, 1997). For example, Webster (1990) found that fifth grade students who used supplemental CAI in their classroom expressed significantly more positive attitudes toward math than similar students who did not receive CAI. Following her two-year research study of the implementation of educational technologies in an urban high school, Schofield (1995) noted that the one striking effect of computer use across the wide variety of applications studied, was enhanced student enjoyment of, interest in, and attention to classroom activities.

Schofield's (1997) review of research on affective and social contexts for the use of educational technologies also suggested that classroom use of these instructional media typically fosters relatively high levels of cooperation and interaction among students. Researchers at SRI found that over time students in technology-using classrooms became more likely to work in small groups on collaborative activities than students in non-technology-using classrooms (Penuel & Means, 1999). In technologically enhanced mathematics environments researchers reported that students expressed a preference for collaboration in their exploration of math concepts, even when the instructor did not formally plan group work (Sheets and Heid, 1990; Heid, 1997). Hoyles Sutherland and Healy (1991) suggested that student collaboration was a natural outcome of the public character of the computer screen, the need for interaction with the computer program, and the need for a joint decision when students shared technology in the math class. Somewhat less obvious than evidenced examples of student collaboration in technology enhanced learning environments, are the descriptions of how these changes in classroom dynamics -including teamwork, collaborative learning and reciprocal teaching, unfold gradually, over time (Salomon,1998).

While the use of classification instruments to assess the qualities of the classroom learning environment for students have been well-documented (Moos & Trickett, 1987; Fraser, 1994; Fisher, 1998), research has not focused on students' perspectives of their experiences within technologically enhanced classroom learning environments over time. Student reports of computer technology use have mainly focused on the frequency of computer use in specific courses, the type of software utilized, and student response to an admittedly rough categorization of activities (Becker, 1994a). Fullan (1991) noted that while people generally think of students as the potential beneficiaries of change, they rarely think of students as participants in a process of change "consequently, there is little evidence of what students think about changes and their role regarding them" (Fullan, 1991, p. 11). Similarly, Cuban (1993b) noted the general lack of research concerning student perspectives on teaching and learning including "information about classroom climate, the impact upon students of different forms of instruction, teacher-student relationships and the students' perspective on teaching" (p. 286).

Given the absence of student perspectives on the their own classroom learning, particularly concerning the process of educational change (Fullan, 1991), this study seeks insight into how students experience the implementation of an interactive learning system in their eighth grade math class. What changes occur in students' actions and interactions within the math class? How do students' experiences with math change during the implementation of this educational technology? How do students' opportunities to interact with the interactive learning system relate to implementation decisions or choices made by the teacher? This study also seeks to explore the teacher's experiences of the implementation process. Simultaneously exploring the implementation experiences of the teacher and the students, and the conditions afforded by their classroom and school milieux during this change in subject matter, is not perceived to be an easy task. However, the present study assumes that neglect of, or inattention to, any of these loci would merely yield a decontextualized, desensitized set of descriptions and interpretations, thereby reiterating the limitations of earlier studies of educational technologies. Methods for engaging this dialogue between students and their teacher, and the milieux and subject matter of their eighth grade math class during the implementation of an interactive learning system are explicated in the following chapter.

CHAPTER 3

RESEARCH METHODS

"It would seem apparent that the context in which human lives are lived is central to the core of meaning in those lives" (Andrews, 1991, p.13). This research assumes that teachers and students are active agents within the classroom. Their classroom experiences are shaped by four dynamic and interactive contexts; teacher, students, subject matter and milieu. These contexts therefore provide useful loci for exploring the experiences of a teacher and her students during the implementation of an interactive learning system in their math class. "The province of qualitative research, accordingly, is the world of lived experience, for this is where individual belief and action intersect with culture" (Denzin and Lincoln, 2000, p. 6). Concern for the life-worlds and voices of students and their teacher, during the implementation process, required the use of qualitative research techniques for this research study. This chapter begins with an overview of the design for this research study. Data collection strategies including participant observation (classroom observations and classroom conversations), and document analysis and interviewing (semi-structured interviews and focus group interviews) are explicated. A description of my role as the primary instrument of research concludes this section on research strategies. Methods for gathering data (documenting and recording data, and transcribing data) and for organizing and analyzing data (grounded theory) are described in detail. This chapter concludes with a discussion of how I develop and maintain Maxwell's (1992) five levels of validity within the present research study.

Research Design

During the Summer and Fall of 2000, I collaborated with RVDP marketing and implementation personnel in Pennsylvania to secure a suitable site for my proposed research. Sites initially identified proved unsuitable, given my criteria for site selection. My interest in a contextualized study of teacher and student use of educational technologies, and the obvious need for this classroom-based research, motivated my decision to consider only those classroom sites where (teacher's planning for, and) students' interactions with the interactive learning system would not be restricted by the number of licenses purchased. I assumed that a setting where all students could potentially have access to the interactive learning system during the math lesson would provide the most suitable context for exploration of the research questions. My request for two or three classes was based on my preference for finding approximately 20 to 30 students who would be accessible to me (not-withstanding the impermeable nature of class-timetabling in school settings). My past teaching experience with regular school populations in elementary and middle schools, and my lack of experience with special populations in these settings rendered me most suitably qualified to engage in research with elementary or middle school classes where the majority of students were not identified as having an Individualized Educational Program[4].

This research can arguably be described as an implementation study. As such, I was compelled to choose only from those sites where planning for, and implementation of, the

[4] An Individualized Educational Program (IEP) describes the special education and related services purposefully designed to meet the unique educational needs of a student with a disability. The program is developed at one or more IEP meetings, and provisions for the student's program are detailed in writing in the IEP.

interactive learning system was scheduled to begin following my completion of the doctoral coursework program at the Pennsylvania State University, and preferably at the beginning of the semester to allow ample time for development of the research project. To facilitate maximum and frequent engagement with research participants in the chosen setting, I considered working only with those schools located within two hours driving distance from my home. Merriam (1988) explained, “One wants to discover, understand, gain insight; therefore one needs to select a sample from which one can learn the most” (p. 48).

Geographically remote, yet educationally connected, the two eighth grade math classes at Westridge High offered an ideal context for exploring the implementation of the RVDP interactive learning system. The implementation of DM in these classes was planned for the early spring, thus affording the possibility for me to explore the teacher and her students’ experiences of the implementation of the interactive learning system over the course of a school semester.

<u>Data Collection Strategies</u>

<u>Participant Observation</u>

Participant observation offered a suitable strategy for listening to and talking with students and their mentors, and observing teacher and student interactions, in the eighth grade math class at Westridge Junior–Senior High School. One key assumption of participant observation has been that by entering into interaction with people in their everyday lives researchers can better understand the beliefs, motivations, and behaviors of their research population, than by using any other approach (Hammersley, 1992). Wolcott (1999) denoted the obvious tension in the term, participant observation. Tedlock

(2000) suggested that the term implies a “simultaneous emotional involvement, yet objective detachment” (p. 465). The *peripheral-member-researcher role* offered by Adler & Adler (1987) initially appealed to me as a suitably active-reflective researcher role for the present study. I considered this a dynamic and fluid role -one which would enable me to partake in the math class where possible, despite my tangential membership within this eighth grade class group. Wolcott (1999) addressed this difference between “being present as a passive observer of what is going on” (experiencing) and “taking an active role in asking about what is going on” (experiencing and enquiring). The former role afforded opportunities for me to explore and describe the eighth grade math class and the teacher and her students’ actions and interactions within it, by making classroom observations and describing these observations in detail. The latter role offered greater opportunity for me to engage in spontaneous, unplanned, informal conversations with students, math teachers, administrative faculty and other staff members involved in planning for the use of RVDP materials in the research setting.

Classroom Observations

As the research study unfolded, I struggled to balance my role as both participant and observer. At times this role was situationally constrained or determined and thus beyond my control. For example, during my first four weeks in the research setting (pre-implementation of DM), I was obliged to observe rather than participate in the regular math class. The class teacher cleared a large table for me at the back of the room. The organizational structure of the regular eighth grade math class did not engender participation on my behalf. However, it did provide ample opportunities for me to describe the research context, the participants' actions and interactions within it, and my own response to this interplay.

I carried a small notebook (approximately 5 x 7 inches) to each math class. I used this research notebook to document any potentially interesting datum within the research setting. As a newcomer to the math class, I anticipated that my opportunities to see this context with *new-eyes* would be transient and short-lived. Therefore, during these formative (first four) weeks of observation in the regular math class, I tried to sketch myself into the research context noting my own reactions, reflections and questions to what was happening around me. I attached classroom observation protocols to pages within my notebook and re-evaluated their utility within the research context in the early weeks. These two observation protocols (the classroom map protocol, and the activity framework protocol -both designed prior to beginning the research study) enabled me to focus my observations by detailing elements of the classroom milieu, and describing the activities of students and their teacher within this milieu.

I used my classroom map observation protocol (Appendix B) to identify the structure and layout of the eighth-grade math class including furniture, storage areas, learning resource areas, whiteboards, wall mounted materials, etc. This protocol also enabled me to identify ownership or use of certain classroom spaces, by observing patterns of teacher and student mobility. I completed my depiction of the regular math classroom, by week two of this research study. When the class moved to the computer lab for the implementation of DM in week four, I used my research notebook to note physical features of the computer room, and students' seating arrangements within it.

I designed the activity framework observation protocol (Appendix C) anticipating some variety in activity structure within the math class. For each student activity observed, this protocol was planned to identify the activity task (what), duration (when), rationale (why), areas (where) and participants (who). I used this observation document during my first two weeks of research to describe the four activity phases within the regular math lesson using the regular math texts. When students began to work on DM activities in the computer lab, I described their activities in my research notebook, and recorded their discussion of these activities using my portable recorder[5].

As the study unfolded, I used my notebook to describe student actions and interactions within the DM math class. In particular I described participants' coverbal behaviors (expressions, gestures, actions), which I hoped might later inform and extend voice-recorded data. I also noted interesting comments or phrases from participants which might not have been recorded on tape. To maintain my research notebook as a valuable private site for documenting my unedited interpretations of participants' actions and interactions, and my own evolving role within the research context, these notes were mostly written in Irish.

Classroom Conversations

Conversations with students and teachers in the research setting (primarily within the classroom) enabled me to come closer to the participants' perspectives regarding the implementation of DM in their math class. Spradley (1979) noted that in these interactions "ethnographers must deal with at least two languages – their own and the one spoken by informants" (p. 17). I am so frequently reminded of my Irish accent and at

[5] Voice-Activated Microcassette Tele-Recorder 12A99 [Portable Recorder] Fort Worth, TX: RadioShack.

times, curious choice of words that it would be remiss to have assumed my language would be spoken with similar intent, nuance, purpose or meaning by this group of American teenagers and their peers and teachers. LeCompte & Preissle, (1993) caution that "researchers studying teenagers… may note that without some careful groundwork in adolescent argot, it is impossible to get beyond adolescent indifference" (p. 95). During the research process, I remained sensitive to the need to identify subtle differences between participants' intended messages and those that I heard.

Combined with classroom observations, these unscheduled verbal exchanges provided valuable opportunities for me to become familiar with "the native communicative repertoire" of participants in the eighth grade math class (Briggs, 1984, p. 24). These conversations, or metacommunicative events, provided crucial information on the interaction between language use and social behavior as a whole, and between social and cultural norms and observed patterns of interaction, in particular (Briggs, 1984). Because many of these metacommunicative routines lie outside the narrow limits of the interview situation, I continuously engaged in unplanned conversations with students and teachers in the regular math class prior and during the implementation process. These conversations informed the development of semi-structured interview guides throughout the data collection process.

During the initial weeks of observation in the eighth grade math class, I searched for opportunities to talk with research participants during the school day. These improvised activities included arriving to the school before the transition bell and strategically busying myself with some task near the students' lockers; sharing lunch with the class teacher in the staff room, assisting teachers with cafeteria duty after lunch, visiting the library during my free period when eighth grade students were often on study break talking quietly with one-another, and working in the computer lab (transcribing interview and classroom conversation recordings) during ninth period when students frequented the lab to finish their school work.

With the transition from the regular math class (and regular curriculum) to the computer lab (and DM activities) in week five of this research study, I experienced many opportunities to talk with students and their teacher in the math lesson. The structure and layout of the computer lab facilitated easy movement between and among students. In addition, the hum of DM voices from 15 or 20 sets of speakers provided a welcome backdrop for non-disruptive conversations with students and their teacher.

Document Analysis

I also collected records of students' work and other text documents within the research setting which I felt would inform my understanding of the experiences of participants prior to, and during, the implementation process. Glesne and Peshkin (1992) insisted that document analysis is an essential part of the process of understanding and contextualizing the research situation. I designed and used a document analysis protocol (Appendix D) to identify the type (what), origin (when created), significance (when received), producer (by whom), intended audience (for whom), location (where), and purpose (why) of any classroom or school document which might inform my understanding of the participants' experiences with the implementation of DM in the research setting. Text documents I collected and analyzed included a printed copy of the school mission, the Saxon math texts (used by the teacher during the regular math class)[6], the teacher resources guide to the Saxon math texts, student homework assignments, the notification to students to prepare for the PSSA exam, the school newsletter, the DM test reports (for the class, and for individual students), the students' DM progress reports, and so forth.

Interviewing

In addition to the aforementioned spontaneous conversations (with students, teachers and staff) at Westridge High, I scheduled periodic, semi-structured, interviews with the research participants. Hammersley & Atkinson, (1995) suggested that "the differences between participant observation (classroom conversations) and interviewing are not as great as is sometimes suggested" (p. 141). They noted the crucial role of the researcher and of context in both. Schwandt (1996) described the interview as "a form of discourse between two or more speakers, or "a linguistic event in which the meanings of questions and responses are contextually grounded and jointly constructed by interviewer and respondent" (p. 79). Locating research participants, calibrating one's self as a research instrument, gaining trust, and establishing rapport with research participants were ongoing researcher activities which furthered the processes of participant observation and interviewing within this dissertation study. Holstein & Gubrium (1995) called for renewed attention to these and other issues representing the *how* and not simply the *what* of the interview. They referred to this holistic and situated event as the *active*

[6] Saxon, J. and Hake, S. (1997). Math 76: An incremental development (3rd ed.). Norman, OK: Saxon Publishers Inc.

Saxon, J. and Hake, S. (1999). Math 87: An incremental development (2nd ed.). Norman, OK: Saxon Publishers Inc.

interview. Behar (1996) offered a similarly fluid (and systemic) perspective of the research interview, noting that all elements comprising the interview event are deeply intertwined. "Increasingly, qualitative researchers are realizing that interviews are not neutral tools of data gathering but active interactions between two (or more) people leading to negotiated, contextually based results" (Fontana & Frey, 2000, p. 646).

Semi-Structured Interviewing

To facilitate dialogical interaction between myself as researcher, and the research participants, I planned semi-structured interviews with the teacher and four of her students. Patton (1990) referred to the semi-structured interview as "the general interview guide approach" (p. 280). I used informed consent forms to communicate the explicit ethnographic purpose of the interviews to research participants. I began each interview with an overview of its purpose, and I invited (and offered to respond to) participants' questions before and at the conclusion of each interview. I used Spradley's (1979) ethnographic questions, the third element in his ethnographic interview (p. 58-68), to develop and sequence my interview guides.

I planned three phases of semi-structured interviews (exploratory, intermediate, culminating) with the eighth-grade mathematics teacher during this fourteen-week research study. The exploratory teacher interview (Appendix E) was scheduled in week three -one week prior to the teacher's implementation of the RVDP interactive learning resources in her eighth grade classes. This interview followed initial, spontaneous, and informal conversations with participants in the pre-implementation setting. It was designed to explore the class teacher's past experiences with math and technology, and in particular, her motivations for implementing DM in her math classes. Observations of, and conversations with, students and teachers in the math class continued to inform the development of interview guides for the intermediate and final interviews with the class teacher. The second teacher interview (Appendix F) was scheduled in week nine. The purpose of this interview was to explore the teacher's own uses and perceptions of DM, and her understanding of students' uses and perceptions of DM within the math class. The culminating interview with the teacher (Appendix G) was scheduled in week 14, the final week of the research study. This interview was planned as an active interview, one that could "acknowledge interviewers' and respondents' constitutive contributions and consciously and conscientiously incorporate them into the production and analysis of interview data" (Holstein and Gubrium, 1995, p. 4). "The interview is an active text, a site where meaning is created and performed" (Denzin, 2001, p. 25).This culminating interview with the teacher was held in two sessions on the same day and lasted almost two hours in total. The purpose of this interview was to discuss in detail the teacher's reflections on, and my interpretations of, her own use and her students' use of DM in the math class. Other topics for conversation included our perceptions and experiences of educational change in general, and educational technologies in particular. This interview marked a departure from the earlier, more formal semi-structured interviews with the classroom teacher. The final, transcribed text (of both voices) reflected the shared contribution of both the teacher and myself to the interview process.

Two semi-structured interviews (Appendixes H & I) were scheduled with individual students during weeks 10 and 14 of this research study. I used naturalistic sampling (Ball, 1990) to select four individual students for semi-structured interviews, "to detail the many specifics that give the context its unique flavor," and "to generate the information upon which the emergent design and grounded theory can be based" (Lincoln and Guba, 1985, p. 201). Combined with classroom conversations and observations, these interviews enabled me to construct portraits (Lawrence-Lightfoot and Hoffman, 1997) or mini-embedded case studies of four students in the teacher's eighth grade math classes (two students from each class). For example, in the first semi-structured interview with students (Appendix H), I asked each student to tell me what he or she thought about math. Many students had frequently expressed their dislike of math within the regular class. The semi-structured interviews with these four students afforded opportunities for me to explore in greater detail phenomena (such as student dislike of math) emergent in the larger class picture. These four portraits also enabled me to explore in much greater detail, the students' perspectives on the implementation of the RVDP interactive learning system in their math class. "Paradoxically, the observer is aware of offering shape to the portrait, and at the same time is aware of being shaped by the context" (Lawrence-Lightfoot, 1984, p. 6). In this study, each individual student portrait served as a rhetorical device, providing vivid renditions of broadly observable patterns of class behavior, and thereby directing and redirecting the most fruitful path of research in answering the research questions. These four richly detailed student portraits, grounded in conversation and interview data, facilitated "the on-going joint collection and analysis of data associated with the generation of theory" (Glaser and Strauss, 1967, p. 48).

Focus Group Interviewing

"The group interview is essentially a qualitative data gathering technique that relies upon the systematic questioning of several individuals simultaneously in a formal or informal setting" (Fontana and Frey, 2000, p. 651). Within the present study, I planned exploratory and culminating focus group interviews with students to explore their experiences with educational technologies and math in general, and DM in particular. Flick (1998) suggested four processes or elements of group discussions which I used to structure the focus group interview guide: brief explanation of the research procedure, preparation for the discussion, discussion stimulus, and process discussion (p. 119-120). Three focus group interviews (each with 5-7 participants) were held with students in weeks four and five of this study. This exploratory focus group interview (Appendix J) was designed to probe students' prior experiences with educational technologies at home and in school, their attitudes toward math, and their expectations for the DM learning system. Information gleaned from this session also helped to inform the selection of students for individual, semi-structured interviews. Three culminating focus group sessions (Appendix K) were also held with students in the final week of the research study. These final focus group interviews offered opportunities for respondent validation or member checking of my own interpretations of students' perceptions and experiences of DM in their math class.

Researcher as Context

I used the aforementioned data collection strategies to come closer to the participants' perspectives of their experiences with DM in the math class. For me, dialogue with participants was foundational to all meaning-making processes within the research context. Denzin and Lincoln (2000) have noted that there is *no clear window* into the inner life of an individual: "There are no objective observations, only observations socially situated in the worlds of-and between-the observer and the observed" (p. 19).

During this fourteen-week research study, I learned to explore and reflect upon my role as researcher. This role was iteratively defined and refined through active dialogue with participants in the research setting. For example, during the implementation of DM in the computer lab, I found it difficult to reconcile my past role as (elementary and middle school) teacher, and my current role as researcher. As students worked through math problems using DM, I resisted the temptation to immediately assist or provide a helpful prompt or answer, until I first understood a student's experience with the math problem. In these circumstances, I learned to protect my research inquiry by waiting to assist a student with a math problem, until I first understood his or her level of engagement and experience with the information provided in DM. In learning to balance these roles, I consistently modeled behaviors which became familiar to students; they learned to first discuss their experience of the math problem with me, before anticipating or receiving my assistance.

Rossman and Rallis (1998) explained that a researcher's relationship with his or her participants is constantly evolving through ongoing negotiations, based on terms and conditions set during entry to the research setting. Lincoln (2001a) noted that while this evolution in relationship, generally referred to as *rapport* "has remained a fundamental given of fieldwork method, viewed as part and parcel of 'gaining entry,'" (p. 3), it's articulation in descriptive terms, within a research context, is problematic at best. Lincoln suggests that sensitivity to difference, to the pluralism of the researcher-participant relationship, is perhaps the only way to resuscitate rapport as a meaningful tool within research inquiry. Within the present study, the relationship between the classroom teacher and myself, the researcher, was characterized by mutual sensitivity to the role, responsibilities, concerns and priorities of the other. Our relationship evolved from an acknowledgment of difference, which enabled us to respectfully and honestly begin to learn from one another. Toward the end of the research study, this evolution in our relationship rendered the semi-structured interview strategy inadequate for extending our discussions regarding the implementation of the interactive learning system in the teacher's math class. My final interview with the teacher is best described as an active interview (Holstein and Gubrium, 1995) designed to reflect the tenor of our regular conversations about the research study during the school day.

Delamont (1992) argued that the qualitative research experience *qualitatively* changes both the researcher and the researched. While it was not my primary intention to improve the quality of action (Elliot and Keynes, 1991, p. 69) within this particular research, my interactions with research participants during this dissertation study increasingly suggested a rejection of both a posture of detachment, and privileged perspective (Lincoln, 2001b). Beyond the role of researcher, I assumed facilitating roles (e.g., teacher's assistant) which, rather than compromising my research questions, enabled me to explore them in much greater detail. Three particular decisions or actions characterized my adoption of an active research orientation within this research project: assisting students with their math following their explication of the math experience, endorsing an active interview format for exchanging ideas with the class teacher, and offering to work with the class teacher and others in the math department to develop and provide professional development opportunities for teachers intending to use the interactive learning system in the 2001-2002 school year.

Data Gathering

Documenting and Recording Data

There are various perspectives regarding how participants' voices should be documented. Lincoln and Guba (1985) "do not recommend recording except for unusual reasons" due to the intrusiveness of recording devices and the possibility of technical failure (p. 241), while Patton (1990) described the use of a tape recorder in research interviewing as "indispensable" (p. 348). Sanjek (1990) suggested that "good ethnographic method includes the observation and recording not just of interviews, but perhaps more importantly 'of speech-in-action'" (p. 211).

In the present study, following Sanjek (1990), I chose to record classroom conversations (with and among participants) during each math lesson, and all scheduled interviews. I assumed that consistent recording of participants' classroom conversations and interviews would enable me to attend to the informants' own words in ways that might not otherwise have been possible. I introduced my battery-operated portable recorder to students and their teacher during my first class visit. I explained that only I would have access to the tape recordings and that students' return of signed student consent forms (Appendix L) and parent consent forms (Appendix M), indicated that they were comfortable having their conversations recorded by me in the math class. Both informed consent forms were returned for each of the 32 students in the eighth grade math classes.

I consistently used my research notebook to describe, interpret, and question what was happening around me in the research setting. In truth, my written descriptions became shorter as the study progressed. I devoted less and less time to writing in my research notebook during the implementation of DM with students in the computer lab, often choosing instead to speak my thoughts into my portable recorder. On the journey to and from the research site, I also recorded my own impressions, perspectives, ideas, hunches, etc., using voice recognition software. Wearing headphones connected to a portable recorder (while driving) I was able to speak aloud my reflections on the research process, for later transcription and retrieval on my PC at home. I compiled these reflective musings in my research journal, which I maintained electronically, and frequently updated, as a word document.

Transcribing Data

In planning this research, I decided to reconstruct my notebook notes, my completed observation protocols, and participants' voice recordings as transcribed texts within twenty-four hours of having initially noted them. On all but two occasions (when heavy snow storms caused me to leave Westridge High School early), I remained in school until all my notes from that particular day had been transcribed. To successfully complete the aforementioned data recording and transcribing activities in the research setting, I accumulated a set of necessary tools, which participants and I found rather amusing. On any given day in school, my *bricolage* (Denzin and Lincoln, 1994, p. 3) began with my portable recorder, back-up microcassette tapes and batteries, a note-book and pencil case, (for recording) and my laptop computer, power cords, external zip drive, back-up zip discs and a set of headphones (for transcribing).

Organization and Analysis of Data

Grounded Theory

Given the documented need for new, theoretically expressed understandings of students' and teachers' experiences of the classroom implementation of educational technologies, I chose to analyze my transcribed research data (classroom observations, classroom conversations, interviews) and related documents, using grounded theory methods. "The value of the methodology… lies in its ability not only to generate theory but also to ground that theory in data" (Strauss and Corbin, 1998, p. 8). Strauss and Corbin explained that the researcher's grounded theory analysis proceeds through an iterative process of describing, conceptual ordering and theorizing. These three activities are foundational to Strauss and Corbin's theory building process and are explicated as follows (p. 25):

1. *Describing* involves depicting or telling a story. In Chapter four I use *description* to portray the pre-implementation process for DM. I describe the school classroom and subject matter contexts, which frame the actions of the teacher and the students in the regular math class. This portrayal is written in the key of developing an answer to the research questions. My descriptions in chapter four are consciously selective, representing what the teacher and her students do, say and make prior to, and during the implementation of DM in their math class.
2. *Conceptual Ordering* refers to the organization of data into discrete categories according to their properties and dimensions. This process represents a move toward increasingly interpretive research activities. The data from my culminating interviews with students and their teacher, represent participants'

responses to *my description and interpretation* of their experiences with the educational technology in their math class. The Interlude at the end of chapter four, offers a bridge between the processes of describing (chap. 4, parts 1 and 2) and theorizing (chap. 5).

3. *Theorizing* entails conceiving and intuiting ideas (concepts) and also formulating them into a logical, systematic, and explanatory scheme. In chapter five, I move along the interpretive continuum into the realm of theory building. I use my descriptions and interpretations of the data to construct a theory which is both grounded in the data, and can be extrapolated from the data -existing purely within the theoretical realm of discussion.

Coding is "the process of analyzing data" (Strauss and Corbin, 1990, p. 61), in order to create theory from data. Grounded theory offered a rigorous set of analysis procedures for coding descriptive data in the present study:

1. Line-by-line analysis: to generate initial categories and discover the relationship between concepts.
2. Open coding: identification of concepts and their properties and dimensions in the data in order to conceptualize categories of codes.
3. Axial coding: reassembling data in new ways by making connections between a category and its subcategories.
4. Selective or focused coding: to integrate and refine the theory.

To facilitate my analysis of data regarding participants' experiences of the implementation of DM in their math class, I purchased *N.5* [7] software prior to initiating this research study. I planned to use N.5 to store, code and browse my transcribed data. Using this qualitative data analysis (QDA) software, I coded the exploratory interview documents (individual teacher interview, and focus student interviews), and classroom conversations, to generate initial categories and to discover relationships between these categories (line-by-line analysis). Table 4 represents a segment from my first interview with Mrs. Hall. I use it to briefly demonstrate my coding processes within the current study.

Line-by-line Coding

I began my analysis of my first interview with Mrs. Hall by reading and scanning the entire document to identify issues, problems and themes. I coded the relevant segments denoting my interpretation of themes, etc. in N.5 as *tree nodes*[8]. At this time, I was more concerned with generating these themes, than prematurely sorting for relevance. For example, I coded the interview excerpt represented in Table 4 under the general theme of *Change*. I then began a line-by line analysis of the interview, asking what each word meant to me, or what I thought it could mean. Beginning with Mrs. Hall's first word in the interview segment presented in Table 4, I noted that her use of "So" could be an affirmation or confirmation of my previous suggestion that she had

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[7] Richards and Richards. (2000). QSR N5 [Computer software] Victoria, Australia: QSR International Pty Ltd.

[8] In their N.5 Reference Guide, Richards and Richards (2000) explain that "the Tree Node system acts like a hierarchical index, or a library catalogue, in that you use nodes in it as categories, sub-categories, sub-sub categories and so on. You can build tree node system before you do any coding…" (p. 66).

done so much in her teaching career. It could also be a qualification or extension of what I had said. Was it an expression of mild exhaustion given what followed, i.e. Mrs. Hall's explanation that she needs 30-35 years of teaching experience to retire? Or did she use it simply to explain that she needed six to 11 more years of teaching experience, in order to retire?

Table 4

Exploratory Teacher Interview: Excerpt

Speaker	Interview Text
SF:	Yes. You've done so much.
Mrs. Hall:	So, this is about my 24th year, and so we're looking at 30-35 years usually for retirement.
SF:	Oh my! And you've had so many different experiences.
Mrs. Hall:	Yes, I enjoyed the elementary immensely while I was there and I thought I would never get used to [pause], you know [pause], I guess its what you get used to. And when I first made the change I thought I would never get used to working with this age of student. And now, I wonder if I could go back to the elementary. You know, because it seems like it takes a lot more energy, there – keeping up with them [laughs]. And you get to like this age student. You know, adolescence is a strange age. This 8th grade year is really difficult for them. But you get to the point, where you really start to like them. And as Mrs. Kline indicated, we really do have very polite students here. (Teacher Interview [TI], 2/8/2001)

Note. This interview excerpt represents lines 55-68 of a full interview with 424 text units (lines).

I used line-by-line coding in this way to closely examine phrases and words within the transcribed data. My interpretations or *codes* became *nodes*[9] in my N.5 QDA project file.

[9] Richards and Richards (2000) suggest that "nodes provide a way of cataloguing all the topics, ideas, people, things, places, etc., in a project… If you think of the documents in a project like the chapters in a

I noted connections or links between the data as I had interpreted them. I recorded these links or relationships between different data by coding the relevant segments and assigning nodes to coded segments.

In engaging this process of line-by-line analysis of data, I had also begun to use open coding and axial coding QDA procedures. Having coded all exploratory interviews using microscopic analysis methods, I analyzed the remaining transcribed data using both open and axial coding methods.

Open Coding

I began by identifying a phenomenon (problem, issue or event of significance to participants) within the data and grouping the categories that represented this phenomenon (open coding). For example, I had identified *change* as a possibly interesting concept within the data (Table 4), and as I progressed through the QDA process, I identified categories of change such as teacher-change, school-change, etc. I began to identify properties or characteristics of each of these categories of change. For the category of teacher-change, career-change became a distinguishing property. I was also able to explore career-change along various dimensions, such as the change from novice to experienced teacher, or from elementary school to high school teacher. This identification of categories and subcategories within the data, and the properties and dimensions that defined them, enabled me to explore certain phenomenon in detail. The

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book, then think of the nodes as like an index at the back of the book that lists anything important that occurs in the book. Nodes can… have as many branching levels as you like. These are called tree nodes, for obvious reasons" (p.64).

phenomenon for the aforementioned example was that of *Mrs. Hall's experience of change*.

Axial Coding

While open coding the data in this way, I began to also use axial coding techniques to clarify the relationships between categories for change, and to identify sub-categories within the data. For example, instructional-change became a subcategory of career-change. Strauss and Corbin (1998) explained that "a subcategory also is a category as its name implies. However, rather than standing for the phenomenon itself, subcategories answer questions about the phenomenon such as when, where, why, who, how and with what consequences, thus giving the concept greater explanatory power" (p. 119). Strauss and Corbin noted that while the researcher might not initially know which concepts are categories and which are subcategories (early in the analysis), this distinction becomes evident to the researcher as his or her coding proceeds.

QDA Software

My use of N.5 for line-by-line, open, and axial coding of data was a layered and iterative process. Having imported transcribed data into the N.5 program, I first coded data as *free nodes* (nodes which existed independent of other nodes). I generated the names for these nodes using participants' own words (in vivo codes) when possible. The resulting free nodes reflected my efforts to ground the analysis of data in the participants' own experiences during the implementation of the interactive learning system in their math class.

In week five of data collection, I began to question the fluency with which I was able to code data in N.5 to generate freenodes. I decided to temporarily cease using N.5, and instead to firstly code printed data transcriptions by hand (noting concepts and subconcepts, etc. in the transcript margins), and then re-code the data in a new N.5 project. This decision to effectively re-code data using pen-and-paper analysis, and then re-enter it in a new project, satisfied my concern for thoroughly questioning the data in order to derive interpretive codes. When I finally checked the nodes I had generated in my second N.5 project, against those in my original N.5 project, I found that my analyses were almost identical. Furthermore, in using traditional pen-and-paper methods to code the data, I found that in addition to listing concepts and subconcepts in the margins, I had also begun to write down my questions, while interacting with the data. Strauss and Corbin (1998) suggested that the QDA process is guided by the constantly questioning researcher who iteratively asks sensitizing questions[10], theoretical questions[11], practical questions[12], and guiding questions[13] of the data. I had begun to document these sub-conscious questions during the pen-and-paper coding process.

I continued to analyze all new data, first by hand, and then using N.5 to generate free nodes. As I became increasingly aware of the relationships between various free

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[10] Sensitizing questions tune the researcher into what the data might be indicating: What is going on her? How do participants define the situation? (Strauss and Corbin, 1998, p. 77).

[11] Theoretical questions help the researcher to see process and variation and thus make connections among concepts: How are these events changing over time? What would happen if…? (Strauss and Corbin, p. 77)

[12] Questions of a practical and structural nature provide direction for sampling and help with the development of the evolving theory: Is this concept well-developed? Where when and how do I go next to gather data for my evolving theory? (Strauss and Corbin, p. 77)

[13] Guiding questions focus the interviews, observations and analyses of documents. (Strauss and Corbin, p. 78). While coding transcripts by hand, I would note ideas or possible questions to be used in interviewing, or during classroom conversations with the teacher and her students.

nodes, I began to re-organize many of these into a hierarchical system of *tree nodes*. In week seven of data collection there were eight categories of data, each represented by a top-level tree node, in my second N.5 project. Four of these eight tree nodes represented Schwab's places for curriculum; milieu, teacher, student and subject matter. I became concerned that I might unconsciously have begun to shape the data according to this curriculum framework. I wanted to check that my use of the N.5 QDA program was not determining the way I was interacting with and coding my transcribed data. "Software should always be subordinated to general analytic strategies and not allowed to dictate them" (Coffey and Atkinson, 1996, p. 192). To once-again examine my own use of N.5 and to ensure that I had not compromised my nuanced interpretive analysis of transcribed data by using the mechanical operations or functions of N.5, I decided to begin a third N.5 project. In this new project, I turned all N.5 codes into free nodes. I decided to maintain a free node, rather than tree node system of node representation, for the remainder of the QDA process. In parallel with my development of a third N.5 project, I began to use the concept-mapping[14] software program, *Inspiration*[15], to engage in axial coding of my free-nodes in N.5. I used Inspiration to explore relationships within (properties and dimensions) and between concepts (concepts and sub-concepts).

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[14] Novak (1990) defined the concept map as a domain-specific "ideational framework" (p. 29). McAleese (1999) explicated the elements of this representational framework by suggesting that a concept map is "a directed acyclic *n*-dimensional graph consisting of a set of n Concept Labels… and a non-empty set of *m* Relationships or Arcs" (p. 351). While this framework supports different representational forms of the concept map, it is generally agreed that the concept map is a knowledge extension tool or a mindtool (Jonassen, 2000).

[15] (2001) Inspiration 6 [Computer software] Portland, Oregon: Inspiration Software Inc.

For the remainder of the QDA process, I was confident that my parallel use of N.5 and Inspiration, following pen-and-paper coding, provided the most useful methods for *integrating and refining the emerging grounded theory*. Weitzman (2000) suggests:

> There are often ways of bending a program to your own purposes. For example, a program may allow you to define only hierarchical relations among codes. You might work around this by creating redundant codes in different parts of the hierarchy, or by keeping track of the extra relationships you want to define with memos and network diagrams. (p. 816)

Selective or Focused Coding

In using these three QDA strategies (pen-and-paper coding, free node coding and concept mapping) I maintained a focus on meticulous and comprehensive analysis and interpretation of participants' words within my data transcriptions. I was confident that my development of grounded theory would not take place at the expense of extracting the essence of my original texts "the interpretations and definitions of situations made by the people in the field under study" (Lonkila, 1995, p. 49). I continued to generate *in vivo* codes when possible. The multiple representational methods for linking categories which Inspiration afforded, provided reassurance that my grouping of codes was more of an *emic* than *etic* representation or interpretation of students and their teacher's experiences with the implementation of DM in their math class.

Charmaz (2000) also emphasized this dialogical relationship between researcher and research participant within the grounded theory QDA process. She advocated a constructivist approach to grounded theory, which shifts grounded theory methods further into the realm of interpretive social science. Within the present research study, grounded theory represented a set of flexible strategies, which focused the inquiry on the meaning of the social realities of eighth grade mathematics students and their teacher prior to and during the implementation of an interactive learning system in their math class.

Qualitative Validity

Flick (1998) noted that this combination of multiple methodological practices, research strategies and perspectives in a single study is best understood as “a strategy that adds rigor, breadth, complexity, richness, and depth to any inquiry” (p. 231). The variety of interpretive methods selected in this study (observation, unplanned conversations, unstructured interview, focus group interview, document analysis, etc.) represent my attempt to secure an in-depth and richly-triangulated understanding of the phenomenon of eighth grade student and teacher use and experience of an interactive learning system in their mathematics class.

Maxwell’s (1992) five kinds of understanding and validity in qualitative research (descriptive, interpretive, theoretical, generalizability and evaluative) were used to guide all phases of data collection and data analysis in this study. Maxwell’s first concern is with the factual accuracy of research accounts (descriptive validity). All of Maxwell’s validity categories are based on this first primary aspect of validity, which requires that “behavior must be attended to, and with some exactness, because it is through the flow of behavior – or, more precisely, social action – that cultural forms find articulation” (Geertz, 1973, p. 17). Within the first four weeks of the research project, I evaluated the utility of my descriptive protocols for classroom observation and document analysis – assessing the extent to which they enabled me to describe what was happening in the math class. Of the three protocols I developed to support my classroom observations, I maintained use of the document analysis protocol only, beyond the second week of this research study. I consistently used my portable recorder and research notebook during the fourteen-week research process, in order to maintain rigorous attention to my own depictions of how students and their teacher were using and talking about the interactive learning system in their math class. I used Schwab's four places for curriculum to provide loci for my descriptions of what was happening between and among these four contexts (teacher, student, subject matter, milieu) prior to and during the implementation of the interactive learning system. I provided guiding questions for my own descriptions, e.g., How are students and their teacher acting and interacting within this milieu, at this time? When I thought I might have been inattentive to the behavior or words of a student or teacher (when I was unable to see or hear, or thought I misheard some activity or conversation within the math class), I asked for participants to recall their activity or words. Similarly, I asked participants to recall words that were inaudible to me during my data transcription process. I used my research notebook to provide reminders to myself, when such checks with students or their teacher were necessary during the following class visit.

I frequently used these checks with research participants, to test my own interpretation of their actions and words within the math class. Interpretive validity is concerned with the researcher's elucidation of the meaning of objects, events and behaviors for the participants engaged in and with them (Maxwell, 1992). The move from description to interpretation is often subconscious (chap. 3, p. 7). Discerning which is which (description or interpretation) often became a difficult if not impossible task, when I reviewed notes in my research notebook. When I thought my interpretation of my descriptions of what was happening in the research context might have been inaccurate, or misconstrued, I asked the teacher and students to provide their own interpretation. Generally, these checks were performed during conversations with participants in the math class. At other times, I felt it necessary to explore my interpretations in more detail, during scheduled semi-structured interviews with participants. The Interlude section at the end of chapter four presents participants' reactions to their pre-implementation and implementation experiences with DM. Their words were elicited in response to my understanding of their experiences, and as such provide a validity check for my interpretation of participants' words and actions within the research context. My use of *in vivo* codes and the generation of emic categories of data where possible, also represent my own efforts to emphasize the primacy of participants' own perspectives, feelings and ideas words and actions, in generating interpretive research data.

Theoretical understanding refers to an account's function as an explanation as well as a description or interpretation of the phenomenon (Maxwell, 1992). Theoretical validity refers to an account's validity as a theory of some phenomenon, and is premised on the assumption that the researcher has first performed some validation of the description and interpretation from which the theory emerges. In moving from interpreting to theorizing within the QDA process, I used concept-mapping techniques (Jonassen, 2000) to relate categories within the data, focusing on emic rather than etic conceptions of how the data were related. I began to explore my own theoretical constructions by creating multiple concept maps, representing the relationships among categories within the data. I also used memos within N.5 to inform the theory building process. By following these steps, I was questioning both the "validity of the concepts themselves as they are applied to the phenomena, and the validity of the postulated relationships among the concepts" (Maxwell, 1992, p. 291). In generating theory from data in this way, I guarded against making unwarrantable claims which the data would not support.

Maxwell's generalizability has two aspects; internal and external. The former is concerned with "generalizing within the community group, or institution studied to persons, events and settings that were not directly observed or interviewed" (p. 293). Thirty-two students participated in this research project of the classroom implementation of an educational technology. The actions, interactions and perceptions of all 32 students and their teacher, provided the focus for this study. To further understand broadly observable patterns within the class group, I selected four students for periodic, individual interview and observation and discussion during the math class. These cases (embedded as portraits within the research findings in chapter 4) are rhetorical devices, which provide exemplars of the patterns observed at class level. In this way, these individual embedded cases provide an especially vivid rendition of broadly observable classroom patterns, and support the broad empirical theory derived from the data. Maxwell's external generalizability is concerned with the extent to which theory derived from data can be generalized to other communities, groups or institutions. Within the present study, the grounded theory that emerges does not assume generalizability within or beyond these eighth grade math classes. In chapter four, I provide detailed and in-depth description of the research setting (teacher, students, subject matter, milieu). Strauss and Corbin note that this description affords "explanatory power"(1998, p. 267) to the grounded theory. The detailed depiction of conditions of the milieu, actions and interactions of participants, and the consequences that incur from these interactions within the milieu, affords the research study "'predictive ability' – that is, the ability to explain what might happen in given situations" (Strauss and Corbin, 1998, p. 267). Indeed, Lincoln, and Guba (1985) caution that it is not the naturalist's task, to provide a specific index of transferability of research outcomes. Similarly, such a claim lies beyond the purview of this study.

The final category, evaluative validity, concerns the validity of evaluative statements (rather than descriptive, interpretive, or explanatory statements) within the research findings. While the analysis of participants' actions and interactions is a vital component in the generation of theory from data, evaluation or assessment of participants' competence in implementing the interactive learning system was not the focus of this study. Frequent use of my research journal and research notebook enabled me to address my own sub-conscious and conscious assessments of the conditions, actions, or consequences observed in the research setting. As previously noted, these personal reflections were documented in my research notebook, and also in my research journal. My descriptions of the research context in chapter 4, while my own interpretations, are not intended to represent evaluative statements concerning the participants or their research setting but rather to engage the reader in the experiences of the teacher and her students, during the implementation of an educational technology in their eighth grade math classes.

CHAPTER 4

RESEARCH FINDINGS AND INTERLUDE

This chapter describes the experiences of an eighth grade teacher, Mrs. Hall, and her 32 students in their math class prior to, and during, their semester-long implementation of an educational technology innovation for math. Wolcott (1992) noted that even basic description involves purpose, audiences, and the selective eye of the viewer. In this chapter, generative quotations from the teacher and her students have been purposefully organized and framed by the narrator-researcher to maintain the reader's focus on the participants' actions and words, during the twice-weekly implementation of DM in their math class. One assumption of this chapter is that the participants' words and actions provide the key to understanding their uses and perceptions of the educational technology innovation in their math class, over time. This chapter is organized in three parts.

Part 1 first describes the geographical and physical contexts for the Westridge Junior–Senior High School, by documenting the researcher's first journey from the Penn State campus, to the research site in south central Pennsylvania, in January 2001. Accompanying the researcher up the icy-steps and through the entrance to the school, the reader meets Dr. Logan, the assistant superintendent of the Westridge School District. Dr. Logan provides a personal tour of Westridge Junior–Senior High school. The reader visits the math teacher, Mrs. Hall, and her students in their regular math class. Descriptions of Mrs. Hall (teacher), her classes (students), their school and classroom (milieux), and the regular math scheme (subject matter) provide the necessary contexts for exploration of their implementation of DM in part 2. The stage is set for exploring how the teacher and her students use this educational technology innovation over a ten-week period during the Spring 2001 school semester.

The implementation story (part 2) unfolds in the Gateway lab where Mrs. Hall and her students use DM on Wednesdays and Thursdays. The new classroom (milieu) and DM curriculum innovation (subject matter) are described. Mr. Mercer, the technology coordinator, is introduced. Mrs. Hall and her students' experiences of the educational technology focus on what participants *do, say* and *make* with DM during their math classes in the Gateway lab. The teacher's primary experiences with DM focus on her use of the testing feature, and her prescription of assignments to reinforce math concepts previously learned by students. As the teacher's use of DM plateaus into a consistent pattern, the action shifts to the students. Features of the DM system that enable students to access math activities in ways which are significant to them, are spotlighted in turn. This section concludes with descriptions of students' activity choices with DM, their experiences with peers in the Gateway lab, and general motivational effects of their use of DM.

Following the implementation drama, part 3 offers an interlude, a brief transition from the findings presented in chapter 4, to the analysis of findings in the final chapter. This segue to chapter 5 summarizes the implementation story from the teacher and her students' perspectives. Quotations have been carefully selected from culminating individual interviews and student focus group interviews during the final weeks of research. This section also eases the reader into the increasingly interpretive analysis (conceptual ordering and theorizing) of the participants' experiences with the educational technology innovation prior to, and during, the implementation process.

PART I: PRE-IMPLEMENTATION

School Milieu: Westridge Junior–Senior High School

Geographical Context

In mid-January, my on-site research began with a 74 mile journey to the geographically isolated town of Milton, home to the Westridge Junior–Senior High school, in south central Pennsylvania. Leaving town, I negotiated the unremitting road construction, shifting lanes, and icy road conditions with the breath-taking views of Happy Valley from Skytop on Bald Eagle Mountain. I followed the descent of traffic onto US Route 220, which modestly serves as the principal north-south link between Interstate 80 and the Pennsylvania Turnpike. Route 220 is a busy road, ill equipped to handle such high volumes of local and commercial traffic. Alternating billboards and road signs encourage drivers to, “Drive nice!” “Save a life!” Occasional scrap yards interrupt the modest dwellings and belie the local reliance on dairy and crop farming.

At Bald Eagle Junction (about 12 miles from the University Park Penn State campus), Interstate 99 provides a welcome reprieve for southbound drivers. I hardly noticed the by-passed towns nestled amongst the hills until reaching Altoona, once an anchor for the Allegheny Portage Railroad (Horseshoe Curve) and a symbol of American industrial prowess. The Altoona Hospital, originally built by the railroaders, is now the largest employer in Blair County. The new baseball stadium, the amusement park, and shopping centers (all visible from the highway) boast Altoona’s capacity to meet the social needs of rural and outreach communities, in addition to its own city population of about 80,000 residents.

After 40 minutes of driving south on Interstate 99, I took exit 23 through East Freedom. I navigated the truck stops, car lots, trailer parks, and auto salvage auctions, which lead toward the small town of Roaring Spring. Beyond a permanent haze of dust, I passed the *Enterprise Stone and Lime* and *Spring Mill Paper* factories, and the *Roaring Spring Water* bottling facility. Bypassing the town, I cut through the cove to South Road 913 towards Martinsburg. The landscape became progressively more rural and unspoilt. The route to Ridgetop Mountain stretched out amongst the rolling hills. I passed the Mennonite girls clad in matching caps and dresses, riding their bicycles through the snow and slush to schools nestled in the valley. Ridgetop Mountain gradually emerged from the farmlands and state game lands, posing an ominous challenge to January travelers. From the summit, the view of the cove was magnificent. I was just six miles from Westridge Junior–Senior High School in Milton.

The village of Stonerstown sits on the edge of Milton town and comprises Milton Borough, which has a total population of about 1,600. Visitors to the borough might be surprised to learn that they are just minutes from Seton Corporation, the largest employer in Bedford County, where the leather seats for their luxury cars have been crafted. With the decline in the mining and railroad industries in the 1950s, a large employment base was lost to residents in Bedford County, which now ranks 63rd in the state's 67 counties in per capita income. Milton is a quiet town. In the morning, the flow of traffic is uninterrupted. Vendors deliver supplies to local hardware and grocery stores. On my first journey to Milton, I passed a modest array of pizzerias, coffee shops, banks and gas stations and the traffic light, which signals the center of town.

I almost missed the road sign announcing the right turn to Westridge Junior–Senior High School and the East Milton Liberty Township. Slowly entering the township, I saw the wooded crest of Ridgetop frame a series of small plots symmetrically aligned by 13 trailers, each facing the road. Though unremarkable in size and shape, each carefully maintained façade regulated the elevated panorama behind. This tidy scene was balanced by a long one-story brick structure just across the road. Overtaking the baseball fields and then the track, I saw the Westridge Junior–Senior High School (built in 1961 and situated on three acres of land) come into full view. I passed the field in front of the school and then the tennis courts before turning left onto the one-way school traffic system. Approaching the back of the school, I parked in front of a window-less trailer (for driver education) painted pale gray and carefully balanced on a wooden platform with attractive wooden steps. In mid-January, I climbed the icy steps of the adjacent district offices to meet with Dr. Logan, the Assistant Superintendent of the Westridge School District.

Physical Context

From my vantage point at the district office door, I caught sight of the Westridge Mission Statement typed on A4 letterhead and posted above the photocopying machine:

> The continuing mission of the Westridge School District is to provide a safe, stimulating and challenging environment where every person has an equal opportunity to attain the knowledge and skills necessary to become lifelong learners who contribute positively to society.

Beyond the hub of busy administrative assistants, I could see Dr. Logan's office door. He emerged from his haven; warm, congenial, and welcoming, and invited me on my first visit of the Westridge Junior–Senior High School. Our tour began on the eighth grade corridor just as the school bell signaled the end of second period. Colorful teenagers juggling textbooks and notebooks stuffed with worksheets and papers darted to their lockers. In a hurried frenzy, girls refined their youthful faces with compact make up mirrors precariously balanced on stacks of books and personal belongings. Others rushed to the restroom or water fountain. Amid the noisy banter, locker doors were wrestled open and slammed shut. The bell for third period sirened students' swift return to classrooms. Half-finished conversations trailed into silence, and teachers' voices gained in authority from behind open doors. The transition was swift, and we entered the vacated eighth grade corridor.

The marbleized vinyl flooring was spotless. Mosaic tiles in soft cool blues and grays lined the corridors past the academic and vocational classrooms, the library, auditorium, cafeteria, gymnasium, two computer labs, and the high school offices. Our tour brought us full circle to the eighth grade corridor and the impressive new Gateway lab, funded by state and federal grants. Dr. Logan explained that such grants had enabled the school to "stay competitive," essentially bridging the gap between the opportunities that prevailed for students in wealthy suburban school districts, and the resources of rural schools such as Westridge Junior–Senior High. Funding recently procured for the school through Educate America[16] and the Technology Literacy Challenge Fund[17] grants, targeted the increased use of technology to support students and teachers in the eighth grade classes, and also students with IEPs in grades seven to twelve. Dr. Logan explained

[16] Under the Goals 2000: Educate America Act funds are appropriated by the Secretary of Education to improve learning and teaching within a national framework for education reform. Grants or contracts are awarded on a competitive basis; pursuant to a peer review process.

[17] The Technology Literacy Challenge Fund provides funding to improve student learning with computers and the information superhighway. Funds are allocated for teacher training and support and for the purchase of computer hardware, networking, and software.

that eighth grade is a benchmark year for students in Pennsylvania, who typically take the Pennsylvania System of School Assessment (PSSA)[18] for reading writing and math in April of their eighth grade year. The Westridge School District administration had looked to technology to improve their eighth grade students' understanding of math concepts. Dr. Logan told me that Westridge Junior–Senior High School had just purchased initial five-year subscriptions for each of their 232 eighth grade students to the RVDP interactive learning resources for math, science, and language arts, with the focus on improving students' math skills.

Teacher: Mrs. Hall

During this first school visit I was introduced to Mrs. Hall, one of the eighth grade math teachers at Westridge Junior–Senior High. During the 2001 spring semester, Mrs. Hall taught 4 of the 6 math classes offered to eighth grade students at Westridge. (The other two classes; Algebra ½ and Math 87, were taught by her colleague Mrs. Lankheit, the Mathematics Department Head.) Mrs. Hall also taught two reading classes during the course of the school day. Mrs. Hall's daily timetable is outlined in Table 5:

[18] The Pennsylvania System of School Assessment (PSSA) is designed to assess student learning and school system programs. Each year, students in grades 5, 8, and 11 in all 501 school districts in Pennsylvania, take the reading and mathematics assessments. In at least one-third of the school districts, students in grades 6 and 9 produce a writing sample.

Table 5

Mrs. Hall's Daily Timetable of Classes

Class Period	Time	Subject	Grades
1	8:11-8:52	Algebra 1/2	8, 9, 10
2	8:55-9:36	Algebra 1	8, 9, 10, 11, 12
3	9:39-10:20	Study Hall[a] Reading[b]	7, 10, 12 8
4	10:23-11:04	Math 76	8, 9
5	11:40-12:21	Lunch & Lunch Duty	
6	12:24-1:05	Reading	8
7	1:08-1:49	Planning Period	
8	1:52-2:33	Math 87	8, 9

Note. [a]Mondays, Wednesdays, Fridays, [b]Tuesdays, Thursdays

Mrs. Hall and Mrs. Lankheit received one half-day of in-service training from the RVDP implementation specialist (Eileen Morrison) in early January. Dr. Logan invited both teachers to implement the RVDP materials with their eighth grade classes during the spring semester. Mrs. Lankheit declined, deferring her use of the RVDP interactive learning system until the following school semester (Fall, 2001). Mrs. Hall agreed to try out the RVDP math resources in her two lower-level eighth grade math classes, for two weekly class periods. She expressed a preference for use of the RVDP system with her lower level classes (Math 76 and Math 87) on two consecutive mid-week days. To facilitate my teaching schedule at Penn State on Tuesdays, Mrs. Hall suggested implementing the RVDP system on Wednesdays and Thursdays. During this (our first) meeting, Mrs. Hall reserved the Gateway Lab for her fourth and eighth period math classes on Wednesdays and Thursdays, for the remainder of the spring school semester.

During the first four weeks of this research (pre-implementation of DM), I learned that Mrs. Hall's teaching career spanned 24 years with the Westridge School District, beginning in 1978 as an elementary school teacher. Mrs. Hall related changes in her teaching career to changes in educational policy at national and state levels. Using her own experiences, she discussed the impact of policy at local level:

> I have elementary certification and I thought that's what I was always going to do: be an elementary teacher. But then I got involved in a remedial math program through Chapter 1, Title, 1[19]… and then there was the mathematics position here [at Westridge Junior–Senior High], the same type of position I had in the elementary, with the remedial math, Chapter 1… And then we changed over to the Option Four Program here where the remedial teacher was in the classroom with the regular teacher… And, eh, from there, then the Title 1 program was phased out here at the high school, and then I just started teaching regular math classes.
>
> (TI, 2/8/2001)

Curriculum change has permeated Mrs. Hall's 10 years of teaching regular mathematics classes at Westridge Junior High. She admitted having become a little more skeptical of change for having lived through it, yet she spoke about her faith in the potential of educational technology to enable positive change:

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[19] Title I of the Elementary and Secondary Education Act (ESEA), was originally passed in 1965 to provide financial assistance to local school districts in planning and providing special programs for educationally disadvantaged children. Mrs. Hall remembers this as the Chapter 1 pullout program. Students were grouped for supplementary instruction based on their scores on the California Achievement Test. A student falling below the 50th percentile became eligible. Title I was called Chapter 1, from 1981 until 1994. In October 1994, President Clinton signed into law the Improving America's Schools Act (IASA). This reauthorized law redefined Title I as a tool for broader school reform.

> You do question as new things come along, I wonder how long this will be here. Because we are used to things changing [pause] usually like with change in governor, in Pennsylvania, for instance. Or something comes along that's federal, then you kind of say, "Well, we'll just ride it out and wait till the next wave." But I really think the technology thing is going to be here to stay. It's just what we do to use it, to help us in our endeavor to educate the students. I mean computers aren't going to disappear; they're only going to get better, and make things better for us, I think.
> (TI, 2/8/2001)

Mrs. Hall explained that limited access to computer hardware and software had restricted her use of educational technology in her teaching at the high school. Her classroom computer arrived at the beginning of the school year, having been ordered one year previously. She used it primarily for personal e-mail communications. Later in the semester, an electronic grade book for monitoring student progress would be introduced to Mrs. Hall and other Junior High teachers, and installed on their classroom computers by a colleague in the history department. An eighth grade student loaded Expert Games[20] on Mrs. Hall's classroom computer earlier in the year. Students who completed their math set before the end of class earned the opportunity to access this gaming software. Mrs. Hall "used to use more computer software… in the elementary, teaching the remedial math. There seemed to be a lot designed for elementary school students" (TI 2/8/2001). She was familiar with math programs that her second and third grade sons used "which probably came with our computer" (TI, 2/8/2001), but much less familiar with high school software programs for mathematics. Mrs. Hall expressed her enthusiasm for implementing the RVDP math resources in her classroom: "As far as using any [technology] with the classes, I'm kind of excited about this [RVDP] because it's going

[20] (1996). Expert Games [Computer software] Coral Gables, FL: The Code Zone: Sweet Software for a Saturnine World.

to be a first too, that we've actually been able to do this" (TI, 2/8/2001). Mrs. Hall articulated her hope that the RVDP system might enliven and refresh her teaching career:

> Maybe, eh [pause]. At some points in your teaching career, you need something to come along to freshen you a little bit. And this could very well, be that. And that's why I wasn't hesitant when he [Dr. Logan] said, "I have a proposition for you" [laughs]. So it might be what I need, to give me a little boost [laughs].
>
> (TI, 2/8/2001)

Similarly, Mrs. Hall hoped that the RVDP materials might also refresh her students: "I think in education, both teachers and students are kind of looking for something fresh (TI, 2/8/2001). She suggested that the RVDP materials might improve her students' interest in math, and their understanding of math relevance, and math concepts, which, she felt were inextricably linked and difficult to address in the regular math class. Mrs. Hall explained that her students didn't readily see the relevance of math and anticipated that use of the RVDP system might increase their awareness of the application of math in their world:

> That's what they always want to know, "When are we going to use this?" You know, they really like to know, that yes, you do use this in everyday life. I like that aspect of it [RVDP] too, that it does show the math relevance, because they don't always get it from the textbook. That seems to be the key. They need to know that it's something relevant.
>
> (TI, 2/8/2001)

The RVDP resources might also improve Mrs. Hall's students' interest in math and their understanding of math concepts: "Sometimes it just puzzles me how to help some of the students, they have such a block against mathematics… it [RVDP] might boost their interest in mathematics because they're used to just doing the homework sets out of the book" (TI, 2/8/2001). Mrs. Hall speculated that students' math achievement might also increase with use of the RVDP resources and result in more positive feelings about math in general:

> If the RVDP resources enable them [students] to understand the concepts a little more, it should improve their self-concept and em, if they start becoming successful, they may have a huge attitude change with mathematics. Cause, eh [pause]. I don't know [pause]. It seems like mathematics is something that is seen as they can either do it, or they can't.
>
> (TI, 2/8/2001)

Mrs. Hall expressed some anxiety concerning her role in initiating change, and her students' roles in responding to this change:

> Well, I'm excited but a little apprehensive, just because you don't know what to expect any time you go to try something new. And you worry what if the kids don't like it, you know what I mean [pause]. Maybe their reaction will be negative and I say, "You know we're still going to do it" [laughs]. That worries me a little bit. But I think once they get into it, they'll be all right. Just because it's new for them too.
>
> (TI, 2/8/2001)

Mrs. Hall's enthusiasm for using the RVDP resources in her math classes was also tempered by her own perceived lack of knowledge about the RVDP system. She felt she didn't know much about it. She told me she received one half-day of in-service from Eileen Morrison (the RVDP Implementation Specialist for South Central Pennsylvania) some weeks previously: "Very nice lady, but we had like, three hours, and she was trying to show us how we could use the internet part, and we looked a little bit at the Destination Math. We looked a little bit at the teacher management" (TI, 2/8/2001). Mrs. Hall was also concerned about the lag in time since she received the in-service: "But then, if you don't use it, you kind of forget what it is you were doing" (TI, 2/8/2001). The district technology coordinator (Rob Mercer) assisted Mrs. Hall by installing the software on each student computer in the Gateway Lab and setting up the administrative system for her: "I've had a couple half-days to work with Rob… And he's been helping me a lot, just trying to learn the management part of it and you know, getting in there, and setting up the tests for them and so on, so I'm really just becoming familiar with it myself" (TI, 2/8/2001). Due to this lack of familiarity with the RVDP system, Mrs. Hall was unclear both about the RVDP materials she would choose to work with, and the manner in which she planned to use them:

> When I get a little more familiar with the internet part of it, it might be interesting to do some of those activities because we did look at a couple of those on in-service day [pause]. So I haven't explored the internet part of it that it much yet to know what's there. That will be my next step, to try to see what's there, on the internet [pause]. Well, since we don't have to just have the one computer, they can kind of work individually although we might see that some of the kind of things they might do better on to work as a pair or with a partner or something. I suppose, we'll [pause]. I'll just be playing that by ear, to see how it goes…
>
> (TI, 2/8/2001)

How would Mrs. Hall's lack of knowledge of the RVDP system affect her implementation of these novel curriculum resources? Mrs. Hall's anxiety regarding her lack of knowledge of the RVDP innovation, was exaggerated by the fact that she would have to continue using the regular math scheme while learning the new RVDP system. Although Mrs. Hall was keenly aware that the school district "wants us to use it [RVDP], because they spent a lot of money on the subscriptions," she was equally aware that the district mandated math scheme should not be compromised in the process:

> I think if the pressure weren't on so much, to cover [pause] a book, per se, you know, you'd feel a lot better about it [pause]. Here we've adopted the Saxon, so any time you deviate from that, you feel like, "Now what are they going to say!" [laughs]
>
> (TI, 2/8/2001)

Subject Matter: Mathematics, Saxon Program

To inform and extend my exploration of Mrs. Hall's implementation of the novel RVDP curriculum resources, I asked the teacher to describe her experiences with the regular math curriculum. Mrs. Hall explained that the district adopted Saxon math program[21] was particularly resilient to external change or innovation:

> The Saxon Math Series, it kind of locks you into following that book. You can't really [pause]. See it's not [pause]. It's really different as far as a math book, because it's not divided into chapters or even concepts, so much as, you know you might be doing one thing one day and the next lesson is something entirely different. But it's incremental, so you can't skip around, you have to go in order, because each lesson will have some of the new problems and some of the ones from all of the previous lessons. It just keeps building. So you can't deviate too much from the math book as far as you're planning is kind of set, because you have to go through it in the order that they have it set up. The only thing you can do is once in a while, you know, you can put in an activity that's maybe not in the book that would be going along with something that you're doing.
> (TI, 2/8/2001)

Innovation in the form of these monthly supplementary math activities was provided by the updated Saxon math scheme. Mrs. Hall noted that the *investigations* or "activity-based variations of the daily lesson" (Saxon, 2001) had been distributed throughout the revised Saxon texts. She explained that these additional activities were designed to prepare students for the PSSA test "to maybe add something that we aren't going to get to before the test, that is usually in the test" (TI, 2/8/2001). Mrs. Hall added that the revised Saxon texts had been carefully aligned to the state standards in math. Teaching to the standards had become synonymous with teaching to the text:

---

[21] Established by John Saxon in the 1980s, the Saxon publishing company produces comprehensive mathematics textbooks for every grade level. The Saxon mission is "To turn around education in America by ensuring access to instructional materials with proven records of success" (The Saxon Mission, 2001).

> In the past we had to follow the text, but now we're doing more things that are towards the standards, which is still basically following the text, because these books have been updated recently, so now they address the standards as well. And they have more activities in them. Like the old books didn't have any of the investigations in them that you might have run across, there are maybe 6 or 8 or 10 investigations in each book and they're pretty much directly related to the standards.
>
> (TI, 5/2/2001)

Mrs. Hall suggested that the pressure teachers feel to teach to the standards is hinged on the monetary reward schools receive for their students' success with the PSSA. She felt this reward system created unrealistic expectations for teachers and students by ignoring differences in students' abilities across grade level:

> I guess really here, just the last couple years, when the governor attached money to the PSSA, that's when the emphasis really became, hit the standards and get them ready for that. But the thing that bothers me about that is that it compares, like, last year's eighth grade scores with this year's. So this eighth grade is supposed to have better scores which –it's not comparing the same kids, and that's kind of what bugs me about that. Whereas if they would look at the kids from maybe fifth to eighth, or eighth to eleventh, where there's some time in there [pause]. So we're not really comparing apples with apples, in other words. Cause sometimes you get a very good class and sometimes, you know, you have a class that's not so good. And that's kind of what they go by. This year's eighth grade has to be better than last year's eighth grade.
>
> (TI, 5/2/2001)

During my first week visiting Mrs. Hall's classes, I learned that all math students at Westridge Junior–Senior High were tracked in the Saxon series at the end of their sixth grade year. They were assigned to math levels in seventh grade based on their performance on the Saxon placement test. Students' seventh grade scores (a combination of achievement on class tests, homework assignments and students' math notebooks) determined whether they would advance to the next Saxon text, or retake or repeat their seventh grade math text. Students' progression to the eighth grade math class was tightly controlled by their achievement within the Saxon series. Mrs. Hall explained that she herself taught the two lower level eighth grade math classes (selected for use of DM):

> Well, the 76 I have would be the lower level, and the 87 would be the middle level, because there's also eighth graders who take Algebra One-half, and there's also some eighth graders who are in Algebra One. So the eighth graders might be in one of four books, and these are the two lower, and really the 87 book is designed for average eighth graders, and maybe accelerated seventh graders.
>
> (TI, 5/2/2001)

Both Saxon textbooks used by Mrs. Hall (Math 76, Math 87) contain 120 incremental lessons in math. Mrs. Hall explained that for herself and her students the lessons were never-ending in the sense that in any given year, they never reached the end of a Saxon textbook:

> Most of the books have, em, anywhere from 120 to 140 lessons. Now you think, well we try to do a lesson a day, which we should be able to get done, but then, some of the books have tests every 4 to 5 lessons, or you can do every other test, and go 8 or 10 lessons in between lessons. So you're sometimes taking a day a week for a test, or a day every other week, and then with all the other interruptions that you get in a schedule, I don't think we get [pause]. I don't think anyone actually gets the book completed. You get close. You get to maybe lesson 110 or 115 out of 128 [pause]. But we're never done.
>
> (TI, 2/8/2001)

Mrs. Hall further explained that each of the Saxon lessons is designed as a blueprint for lesson planning. The Saxon texts minimized Mrs. Hall's lesson preparation time:

> The Saxon approach is a highly structured one. At the very earliest grades the program is scripted so teachers know exactly what to say and how to say it. Furthermore, all Saxon programs are divided into individual lessons to be covered sequentially. The difficult work of lesson planning is already done for teachers. The highly prescriptive nature of the Saxon program ensures that students in different classes throughout a district will not only cover the same material but will do so in a uniform and consistent way. (Saxon, 2001)

Mrs. Hall used block lesson plans to prepare her math lessons and explained, “If you write down the title of the lesson from the Saxon book, it’s pretty much the objective.” The four steps in each Saxon math lesson are described in Table 6:

Table 6

Saxon Math Lesson Components

Lesson Component	Description[a]
1. Warm-up Activities:	Emphasizing speed helps to automate the recall of basic facts.
2. Example Problems:	A brief presentation of this new increment should lead promptly to the practice problems.
3. Practice Problems:	The practice problems are designed to provide massed, guided practice on the new skill or concept.
4. Problem Set:	The conscientious completion of the daily problem set is essential for student success in the program.

[a](Saxon, 1992)

Continued practice and repetition are hallmarks of the Saxon regime. Teachers are advised not to lecture for too long. Saxon (1997) explained, “Mathematics is not difficult. Mathematics is just different, and time is the elixir that turns things different into things familiar” (p.2). During these early conversations, Mrs. Hall described the contexts for her students’ regular eighth grade math lessons, focusing on the district-wide adoption of the Saxon math scheme. My depiction of Mrs. Hall’s conceptualization of this context for her 8th grade math curriculum is provided in Figure 2:

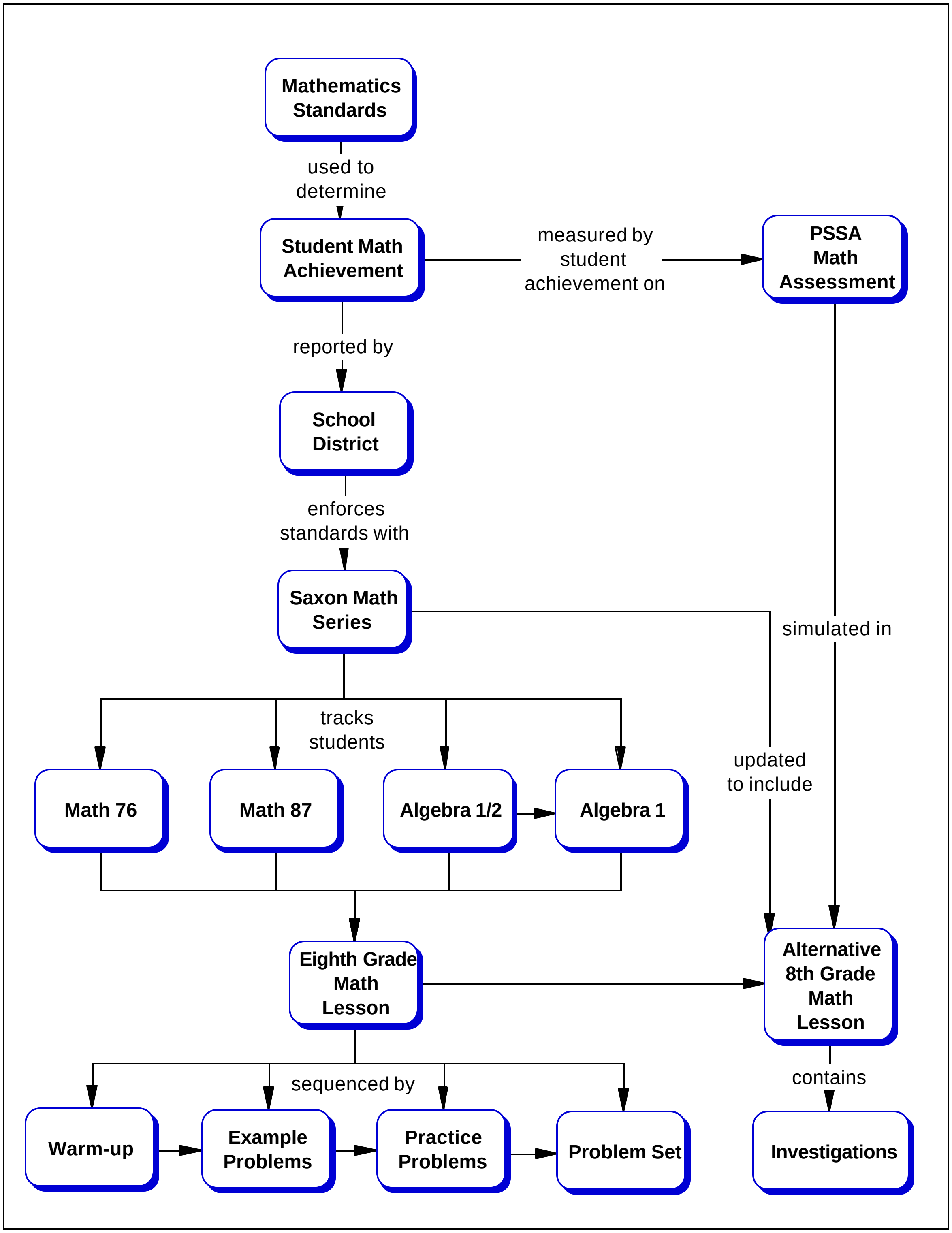


Figure 2. Mrs. Hall's 8th Grade Math Curriculum Context

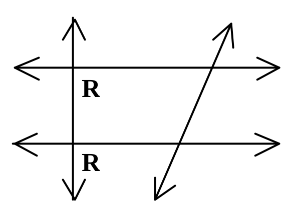
Classroom Milieu: 8th Grade Math

During my first four weeks of research at Westridge Junior–High, I had many opportunities to observe Mrs. Hall's two eighth grade math lessons using the Saxon scheme. These observations enabled me to learn about Mrs. Hall and her students' use of the regular math scheme, as a necessary precursor to my exploration of their implementation of the RVDP curriculum resources. From my observation station (seated at a long table behind students and facing the front of the classroom) I had full view of the classroom math scene. In the first two weeks of field research, I described Mrs. Hall's classroom as follows:

> Thirty forward-facing study-top desks occupy the center of Mrs. Hall's classroom. Each evening, the Westridge Junior–Senior High cleaning staff tweak this finely-tuned symmetrical alignment of study units. Without variation, students are seated at the same desks for each Saxon math lesson; five columns and six rows –almost enough players for half a human chessboard… Facing Mrs. Hall's students, a wall-mounted chalkboard extends almost the full length of the top of the room. It is cut off by a large wooden press, which occupies the front right corner. Unobtrusive behind the classroom door, this press is locked at all times and contains Mrs. Hall's personal and professional belongings and the keys to other Westridge classrooms including the computer lab. Mrs. Hall's table sits in the opposite corner at the front of the room, dwarfed by her tall wooden lectern. While seated at her table, Mrs. Hall frequently becomes invisible to her students, hidden behind permanent piles of paperback novels, student journals and math texts. Student notebooks and manuscripts (and graphing papers) also line the window ledges beside Mrs. Hall. At the back corner of the room (where I am seated, directly opposite Mrs. Hall), Saxon text-books are stacked high on a large set of old wooden bookshelves. Students who complete their homework assignment during class time deposit their textbooks here for later retrieval. Beyond these bookshelves, past the locked filing cabinets, a tall, squeaky, swiveling trolley, standing at the center of the back wall, holds 20 or 30 paper-back novels, and a lone poster on the notice board behind proclaims, "Reading is Fun!" Mrs. Hall's classroom computer inhabits the fourth classroom corner. With her permission, students who complete their assignments early may use it to play math games.
>
> (Observation Notes [ON], 2/8/2001, 2/9/2001)

Mrs. Hall's regular math lesson typically began with a review of homework. Students, seated at individual desks facing the chalkboard, would retrieve their homework assignments on loose pages from their math binders. The homework assignment was rarely completed by all students. Students lost points for not turning in homework, but were not subject to additional penalties or reprimands. Mrs. Hall would provide the answers to assigned homework questions, sometimes pausing to give a verbal or graphical explanation:

> Saxon Math 76, Lesson 75, Question 29
> If b equals 12 and h equals 9, then what does bh/2 equal?
>
> Mrs. Hall tells the class that two numbers that are not separated by any mathematical sign, are to be multiplied. She writes the question on the chalkboard as follows:
>
> $$bh/2 \quad = \quad 12.9/2$$
>
> Saxon Math 76, Lesson 75, Question 30
> Draw a pair of parallel lines. Draw a third line perpendicular to the parallel lines. Complete a quadrilateral with a fourth line that intersects but is not perpendicular to the pair of parallel lines. Trace over the quadrilateral that is formed. Is the quadrilateral a rectangle?
>
> Mrs. Hall draws this final homework question on the chalkboard as follows:



> Mrs. Hall: Why is this not a rectangle? [no response] Because it has only two right angles [pause]. Is everyone ok with this? [no response]
>
> (ON, 2/14/2001)

In Mrs. Hall's regular math class, students graded their own homework assignments. When all homework had been scored, Mrs. Hall would present the new increment (the example problems) on the chalkboard, succinctly portraying diagrams and accompanying explanations. Mrs. Hall explained, "I like to be organized in my presentation of the material" (TI, 5/2/2001). Students would remain mostly silent during Mrs. Hall's presentation, occasionally responding to, or posing, a question regarding the example problems. Mrs. Hall explained that her students were "maybe not always real motivated, but they're pretty polite" (TI, 5/2/2001). When students disengaged from the math lesson, or became involved in non-math activities, they generally did so quietly, and without interrupting Mrs. Hall's explanation of the example problems:

> Brian swivels in his seat to make eye contact with CW. CW nods his response. With rehearsed gesture and expression, a colorful, silent conversation ensues. Mrs. Hall continues working on the chalkboard [now on the first practice example]. AA leaves her seat, returning with graph paper for Beth, but not for herself. Mrs. Hall completes this diagram of problem one, and proceeds to the next. KM quietly walks to the back of the room to sharpen his pencil. DB pencils-in the finishing touches to a sketch that is indistinguishable from my vantage point at the back of the room. Although Mrs. Hall's explanations proceed undisturbed, six of the eighteen students present, are visibly not engaged in math.
>
> (ON, 2/12/2001)

Following her presentation of the practice problems, Mrs. Hall would assign the daily problem set to students as the homework assignment for the next class session. She would then busy herself with correcting, or logging student homework at her table. Students would work quietly on their problem set, until the first bell announced five minutes until the end of the class period. Then students would quietly pack up their math books and papers and shuffle their belongings to a seat near a friend with whom they would chat quietly until the next bell signaled the end of class.

> At the five minute bell students pack up their books, and chat amongst themselves. No reminder is provided regarding the homework assignment, or math work due for the next session.
>
> (ON, 2/8/2001)

Students: Eighth Grade Math

Initial observations of, and discussions with, students enabled me to learn about their experiences in the regular math class and with educational technologies at home and in school. Occasionally, one of Mrs. Hall's students would complete his or her homework assignment early thereby earning the opportunity to use the gaming software on her computer at the back of the room.

> Nine minutes before the end of the fourth period, at 10:55, KM leaves his seat and begins to work at Mrs. Hall's computer station at the back of the room. I ask him if I can pull up a chair beside him, and he nods his answer.
>
> Researcher: You're completely finished with Problem Set 76?
> KM: Yes. I did that on the bus this morning.
> Researcher: On the bus. Wow! How come?
> KM: To get time on the computer [pause]. Look at all these math games!
>
> (CC, 2/14/2001)

Mrs. Hall's students were fluent in their discussion of computer games and simulations for math learning. They vividly described various software programs they had used in the elementary grades to learn math:

> JC: We used it for the times tables.
> Researcher: What did you use?
> AM: Math Splash.
> JC: It helped you, on like your math tables.
> Researcher: Ok, and how much time did you spend on it?
> JC: Like an hour or two.
> AM: We used it every day!
>
> (Focus Group Interview [FGI], 2/15/2001)

> Beth: On the computer in our school, we had something like math

	monsters or whatever, I don't know.
JC:	In sixth.
Beth:	Nah! It wasn't sixth grade. It was more, like fourth!
JFrs:	Third and fourth!
Tanya:	It was just like math problems and it would say, like multiples of, like, o [letter *o*] times three, and you have to go through, and like, eat all the, like zeros, like before you get attacked by the ...
AB:	[Interrupting] Monsters!
AH:	The monsters will get you!
Researcher:	What did you think of Word Monsters. Did you like it?
DF:	Yeah!
BM:	I thought it was a good idea.
Brian:	Yeah.

(FGI, 2/15/2001)

Students explained that they had not yet used computers in their math classes at Westridge Junior–Senior High, although they used computers in other classes to perform various tasks:

To draw:

Chris:	In drafting, you draw pictures on the computer. They have a drafting program on the computers, and we use that everyday.
JF:	For drawing.
JL:	Em, to make lines and, eh [pause].
JC:	[Interrupts] Drawings, yeah. Like 3-D dimension drawings, to make houses. It's on auto-sketch.

(FGI, 2/14/2001)

To write reports:

Chris:	To write a report [pause] for social studies.
JM:	We wrote a report in Powershop. We had to write a report about a career we wanted to do that involves power tools.
JF:	Em, to make lines and, eh...
Tanya:	For study skills [pause]. Em, they just teach us, em like [pause] different things for like reports and stuff, to make them look nicer. Em, like the right way to like, type a letter.

(FGI, 2/14/2001)

To study topics:

Chris:	In eighth grade we used that health [pause]. What was it?
JM:	Oh yeah! There was things about AIDS and that kind of stuff.
JF:	Was that in health class?
Tanya:	Yeah we had all kinds of games about, em different kinds of diseases and things.
Researcher:	So you got information, was that it?
Tanya:	Yeah. And they had little kinds of quizzes and stuff.
Researcher:	Ok. Did you remember some of that information? Do you think you learned from using the program?
RP:	Yeah. More than you would learn out of a book.

(FGI, 2/14/2001)

To learn a language:

AB:	We use them for Russian.
Researcher:	For Russian? Who learns Russian?
All:	[Laugh] We do!
AH:	With Miss Rogers.
AB:	We use discs.
BM:	Yeah. It's like the same as we do for the Spanish One and Spanish Two.

(FGI, 2/21/2001)

Twenty-six of the 32 students in Mrs. Hall's classes had regular access to a computer at home. These students enthusiastically described their use of computers to "get on the internet" (FGI, 2/21/2001) and "surf websites" (FGI, 2/14/2001). One student confidently declared, "I use computers all the time to look up things for school" (FGI, 2/14/2001). Students' favorite computer uses included playing games (freely available on sites such as, Candystand[22], Newground[23], and Shockwave[24]), and chatting with their

[22] Candystand.com claims to be the best free Shockwave gaming site on the Internet, offering 40 games for users to choose from (http://www.candystand.com).

buddies using America On-Line's Instant Messenger[25]. Students in these exploratory focus group sessions were unanimous in their endorsement of computer technology "You're there, and there's so much stuff that you can do. You can look for stuff for a report, or just go to shockwave and play games and stuff. It's cool!" (FGI, 2/15/2001) The students explained that computers "make things easier" (FGI, 2/15/2001), "better, cause you can get it done faster" (FGI, 2/15/2001), "more accurate," and "convenient" (FGI, 2/15/2001). One student suggested that "you'll get more done if you're on the computer." Another noted that "time goes faster when you're on the computers." A third student qualified her peers' comments by proclaiming, "You're having more fun, so it seems a lot faster!"

When asked about their hopes and expectations for the RVDP program, one student in Mrs. Hall's classes noted that "it would be better to do it [math] on the computer, but, I wouldn't be, like, that *into it*." Students described the attributes of a successful program in math with little hesitation. They agreed that it should be "funny looking… like make you laugh" (FGI, 2/14/2001) and "it should probably have good graphics. Because if the graphics are bad, you probably don't want to spend a lot of time on it" (FGI, 2/15/2001). One student suggested that math would become more interesting if learned in a game

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[23] The Newgrounds web site offers visitors a large selection of games (featuring the weekly top ten selection), a web portal (for uploading and downloading Flash movies), and additional web downloads (http://www.newgrounds.com).

[24] Shockwave.com claims to give users the best entertainment experiences on the Web, offering the latest interactive games, cartoons, puzzles, greeting cards, music and more (http://www.shockwave.com).

[25] AOL instant messenger software is freely downloadable from the AOL web-site (http://www.aol.com). Users do not pay for their first 1,000 hours of AOL service.

format "like having just a plain page, maybe, like, make every problem, a game, some sort of a game" (FGI, 2/21/2001). A peer added that "maybe if we had the math problem on there, we could have a calculator on there too, next to it" (FGI, 2/21/2001). Chris agreed that "you learn better and more faster if you actually have a hands-on-experience" (FGI, 2/14/2001). From the outset, students in Mrs. Hall's class expressed their interest in educational technologies, and the use of novel tools for instruction in the regular math class. Students looked forward to the implementation of the RVDP interactive learning system in their eighth grade math class.

Four Student Portraits

While Mrs. Hall's students spoke very positively about their experience with educational technologies at school and in their homes, they generally spoke with much less enthusiasm about their experience with math. During weeks three and four of this research project, I asked each of Mrs. Hall's students how he or she felt about math. (I posed the question during individual conversations with each student at math or lunch transition times.) Not one student suggested either liking or enjoying math. Why? More lengthy conversations with individual students enabled me to further explore their dislike of math and additional broadly observable patterns in the data. I selected four students from Mrs. Hall's two eighth grade classes (two from the Math 76 class, and two from the Math 87 class). These four "individual faces and voices are rendered in order to tell a broader story about the … culture" (Lawrence-Lightfoot, 1983, p.7). In the present study, I selected individuals from whom I could learn about students' perceptions of the implementation of the RVDP resources in their math class. I asked Mrs. Hall to suggest individual students whose demonstrations and discussions of their interactions with DM might represent, to some extent, those of the larger class group. Mrs. Hall described each of her students by focusing on two sets of attributes; the student's abilities with math (math skills), and his or her work habits (work ethic). I decided to choose four students who represented different combinations of these two attributes. Informed by Mrs. Hall's descriptions, profiles of the four students I selected are outlined in Table 7:

Table 7

Portraits of Four Eighth Grade Math Students

	Math Level	Class Scores			Work Ethic	Math Skills
Tanya	Math 87 (ML)[a]	B	B	B	Very Good	Above Average
Chris	Math 87 (ML)	B	C	D	Excellent	Below Average
Beth	Math 76 (LL)[b]	A	A	B	Very Good	Average
Brian	Math 76 (LL)	C	C	C	Poor	Above Average

Note. My rendition of Mrs. Hall's description of four of her students.

[a]ML = Middle Level eighth grade math course, [b]LL = Lower Level eighth grade math course

The following initial sketches for each student portrait focus on the student's profile in Mrs. Hall's math class, his or her feelings toward math, and additional reasons for my selection of this student.

Tanya

Like many of Mrs. Hall's students, Tanya had previously taken the Math 87 course with the Math Department Head, Mrs. Lankheit. She had progressed to the Algebra ½ course at the beginning of the school year, but found the introductory algebra course "way too difficult." Tanya asked if she could retake the Math 87 course in her ninth grade year. In Mrs. Hall's class, Tanya had been scoring As and Bs and Mrs. Hall told me "she's really above average" (Classroom Conversations (CC), 2/21/2001). Mrs. Hall also noted Tanya's strong work ethic. "She likes to work it [the math problem] out until she gets it solved and always completes her homework" (CC, 2/21/2001). Tanya's math scores for the previous three grading periods were consistently high (91, 91, 85). Despite her recent success, Tanya expressed little interest in, or enthusiasm for, math:

> Researcher: So, Tanya, what do you think about math?
> Tanya: I don't like it.
> Researcher: Why?
> Tanya: Because, I don't understand it that well. It just takes too much time to do. I don't like it.
>
> (CC, 2/28/2001)

During the spring semester at Westridge Junior–Senior High, Tanya had many demands on her time; she played on the school's softball, basketball and track teams. Vivacious and friendly, Tanya was well-liked by her classmates, and responded positively to her neighbors' calls for assistance during the initial weeks of her use of DM in the computer lab. Based on Tanya's above average rating for math performance and work ethic (from Mrs. Hall) and her adoption of a mentoring role within the DM lab (I had not seen Tanya demonstrate this role in the regular math class), I was interested in learning more about Tanya's experience with DM. Given her detailed and frequent responses to questions during one of the exploratory focus group interviews with students, I was confident that Tanya would be willing to discuss her DM experience with me. I decided to work around her hectic evening-timetable and frequent changes in schedule, in order to plan individual interviews necessary for the construction of her portrait.

Chris

Chris was also a student in Mrs. Hall's Math 87 class, having taken Math 76 with Mr. Rehrig in seventh grade. Mrs. Hall explained that Chris compensated for his "below average" ability in math by diligently completing all class and homework assignments: "Although there's a lot of things here that he doesn't understand, and he doesn't do real well on the test, then he does all his homework and his notebook and things, and that brings his grade up to a C" (CC, 2/22/2001). Mrs. Hall explained that Chris' grade in Math 87 had been dropping steadily since the beginning of the year. She showed me Chris' scores for the past three grading periods (89, 80, 71) and explained, "So he keeps dropping as it gets harder as we go through the year, because from the beginning it's probably repeated from the previous year" (CC, 2/22/2001). Chris talked candidly about his own perceptions of his mediocre ability in math, and his lack of recent success with math:

> Researcher: What do you think of math?
>
> Chris: Math? I don't like math [laughs quickly]. Math is like my worst subject [pause]. Em, when I first started in school, like em in kindergarten, it was my favorite subject. And then I kind of started getting bad at it, so I kind of dropped that. And now history is my favorite class. But [pause] I can do it, but it's hard for me.
>
> (CC, 2/28/2001)

During their first weeks using DM in the lab, I asked a number of students to think aloud their thoughts while completing DM test questions. Chris readily adopted this communicative device, fluently describing his thoughts as he completed math questions. Chris' persistence in resolving math problems and his exhaustive explanations of each step in the problem solving process, yielded richly detailed descriptions of his experience with DM problems in tutorials and workouts.

In contrast with Tanya's high level of social interaction in the math class, Chris generally worked quietly and independently through the DM math problems. Mrs. Hall explained:

> He's very quiet in class, doesn't cause any trouble [pause]. In fact he's really quiet in class, doesn't ask a question. That's why I was so glad that you were getting something out of him, because it's just that he doesn't say much. Now, he'll answer questions, so he does have enough confidence to answer.
>
> (CC, 2/21/2001)

Chris' enduring hard work with math combined with his low-average math scores, his tendency to choose to work quietly by himself in the DM lab, and his willingness to describe his math experiences to me, rendered him a most suitable candidate for construction of the second student portrait in Mrs. Hall's Math 87 class.

Beth

Beth completed the Math 65 class in seventh grade with Mr. Rehrig, and was now taking Mrs. Hall's Math 76 class. Like Chris, Mrs. Hall told me that Beth was a good worker who's consistent effort on "notebook and homework assignments pull up her grade" (CC, 2/22/2001). Mrs. Hall explained, "She always has her homework done and she has done very well in the tests. Although she may not have as much ability as the other students at her level, her hard work pays off, and she does pretty well" (CC, 2/19/2001). Beth's consistent success with Math 76 coursework and tests, placed her in the top five students in her class for each of the three recent grading periods (95, 94, 92).

Despite this measure of success, when I asked Beth how she felt about math, she echoed Chris's sense of struggle in the regular math class:

Researcher:	I was wondering if you could tell me what you think of math?
Beth:	I don't like it really.
Researcher:	Why?
Beth:	I [pause] it's my worst subject.
Researcher:	Is it your worst subject? Wow! I thought you were doing so well in math.
Beth:	I have a 92.
Researcher:	Yes. That's wonderful!
Beth:	[Shaking her head] But it's hard.

(Student Interview [SI], 4/5/2001)

My conversations with Beth in the early weeks of this study were heavily punctuated with silence. Beth deliberated upon each question posed, and appeared confident with her eventual response. Beth became increasingly expressive in her conversations with me, often embellishing her words with elaborate hand and arm gestures, and with dramatic facial expression. In the math class, Beth divided her time between independently working quietly with DM, and engaging in lavish strategies to synchronize her tutorials with the students on either side of her.

Given Beth's lack of confidence and interest in math in spite of her consistently high grades, her demonstration of both independent and more social uses of DM, and her thoughtful reflection on, and response, to questions concerning her experiences with math, I decided to extend my conversations with her through the school semester.

<u>Brian</u>

Brian was repeating the Math 76 class, having previously used the 76 Saxon text-book with Mrs. Hall in eighth grade. Mrs. Hall told me that Brian "can pass the test and do pretty well, but he doesn't like to do any homework, or use the book so has the ability and knows when to use it" (CC, 2/19/2001). Brian was demoted from the Math 87 class earlier in the school year:

Brian:	Like I started out the year in 87 (Saxon text for eighth grade students), but I just never did my homework, so they put me back down to this.
Researcher:	Ah, and this is what, 76?
Brian:	Yeah. It's 76. I was using that book that's there. [Brian points to an 87 text, on someone's table.]

(SI, 4/4/2001)

Mrs. Hall explained that despite being "above average in ability" (CC, 2/21/2001), Brian's poor work habits significantly reduced his final math grade for each grading period. Reviewing his recent math report scores in the 76 class (80, 83, 78), Mrs. Hall highlighted the gap between Brian's high math test grade, and his poor performance on in-class and take-home assignments:

> Now Brian pretty much based upon [pause]. His test average is higher than this [final math grade], but then [pause]. The homework counts as part of their grade, and they have to turn in a notebook that counts as part of the grade, and you see here that pulls him right down to a C. These are all Cs. Our C is 78 to 84, and then B is 85 to 92. So his test grades were 90 to 95s but then he gets pulled down here.
>
> (CC, 2/21/2001)

During my first four weeks in the regular math class, I noted that Brian seldom turned in a completed math homework assignment to Mrs. Hall. When I asked Brian what he thought of math, he told me he was bored with math; that it just wasn't any fun for him:

Researcher:	So, what do you think of math, Brian?
Brian:	Well, I know I'm good at it, but it's just [pause]. It aint fun at all to me. I don't like it.
Researcher:	Really?
Brian:	Yeah.
Researcher:	Why?
Brian:	Eh, I don't know. I just can't find nothin' fun about math.
Researcher:	Right. So do you think it's important?

Brian: Oh, it's pretty important, yeah. But there aint nothin' fun about it either.

(SI, 4/4/2001)

Brian spoke frequently about his lack of interest in math. He rarely spoke to Mrs. Hall, or to other students, about math in the regular math class. Brian's detachment from the regular math lesson was generally unobtrusive; he would gaze beyond the classroom window, initiate quiet or even silent conversations with his friend, CW, or doodle in his math notebook, during class time.

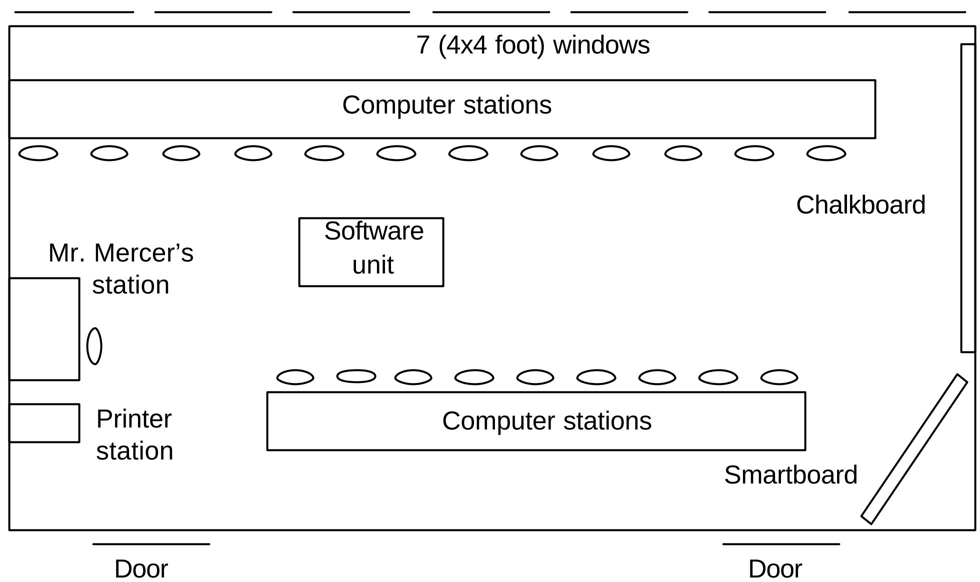
From the outset, Brian expressed his interest in using educational technology in general, and in using DM to learn math. Given Brian's disaffection with the regular math class, his "above average ability" but poor performance on math assignments, and his initial interest in using DM to learn math, I was interested in learning more about how Brian would experience the transition from the regular math class, to the DM math sessions in the computer lab.

PART II: IMPLEMENTATION

Overview of New Classroom: The Gateway Lab

The physical transition from Mrs. Hall's regular math class to the Gateway computer lab began in week five of this research study. By maintaining my focus on participants' primary experiences within their math class, I also began to answer the question concerning how the RVDP educational technology innovation was being implemented by students and their teacher. On Wednesdays and Thursdays (following brief announcements in the regular math classroom), students in Mrs. Hall's Math 76 and Math 87 classes would use DM in the computer lab for the duration of their math class. On these days, students would begin the math lesson in Mrs. Hall's classroom. Mrs. Hall would generally collect students' math homework, inform students of the most recent teacher-assigned DM test, and occasionally check attendance. Mrs. Hall would retrieve the keys to the Gateway lab from the large press behind her classroom door, and all students would follow Mrs. Hall to the lab directly across the corridor.

The Gateway lab at Westridge Junior–Senior High contained 22 new EV700 Gateway Select computers, each equipped with 120 megabytes of RAM, a Pentium 3 processor, 17 inch monitor, and either a pair of Menion speakers with low volume settings, or a set of newer multi-media speakers. The computer room was spacious (having previously contained two classrooms), and bright (flanked by seven large windows on its exterior wall). Figure 3 provides a layout of the Gateway lab floor plan:



Note. This floor plan is not drawn to scale

Figure 3. The Gateway Lab Floor Plan

During the school day, Mr. Mercer (the Westridge School District Technology Coordinator) would return periodically to his computer station in the Gateway lab. This computer station (near the door of the computer lab) would masquerade as Mr. Mercer's office, and successfully so, as it was frequently used by students for their own schoolwork when Mr. Mercer was out on-call. When in situ, Mr. Mercer was available to assist teachers and staff in the Westridge School District with hardware and software troubleshooting. On any given day, Mr. Mercer might be busy repairing the electronic billing system in the cafeteria, researching an optimal video-security system for the school, transferring software from the old to the newer Westridge School District server, or showcasing the Gateway lab facilities to interested local employers.

Overview of New Subject Matter: Destination Math

Following Mrs. Hall's decision to implement the RVDP resources in their eighth grade classes, Mr. Mercer provided support in planning for this implementation process. In preparation for Mrs. Hall's implementation of DM with her Math 76 and Math 84 classes on Wednesdays and Thursdays, Mr. Mercer installed the software for DM Course IV (Appendix A) on the Westridge School District server, and stored the software CDs in the in-built storage units in the Gateway lab. He also received, and passed-on, the following DM materials to Mrs. Hall:

1. A DM user-manual which included an overview of DM (philosophy and purpose) and four informational sections:
    i. Using DM
    ii. Using the Management System

iii. Working with DM

iv. Using the Graphing Tool

2. A packet of student materials which included worksheets designed for:

i. Student use with each tutorial session (Student Log-Book)

ii. Student review of each tutorial session (Your Turn)

iii. Student review of each unit (Unit Review)

iv. Assessment of student understanding of each unit (Unit Assessment)

Final preparations for Mrs. Hall's use of DM with her two eighth grade math classes involved inspecting the currency of student access to the Westridge School District server. Mr. Mercer performed this check and provided Mrs. Hall with a list of user names and log on passwords for each of the 32 students in these two math classes.

To access the DM main menu screen students would log onto the Westridge server, select the DM shortcut on their computer desktop, and enter their username, password, and class when prompted. The main menu screen, illustrated in Figure 4, would be displayed for students who successfully logged-on:

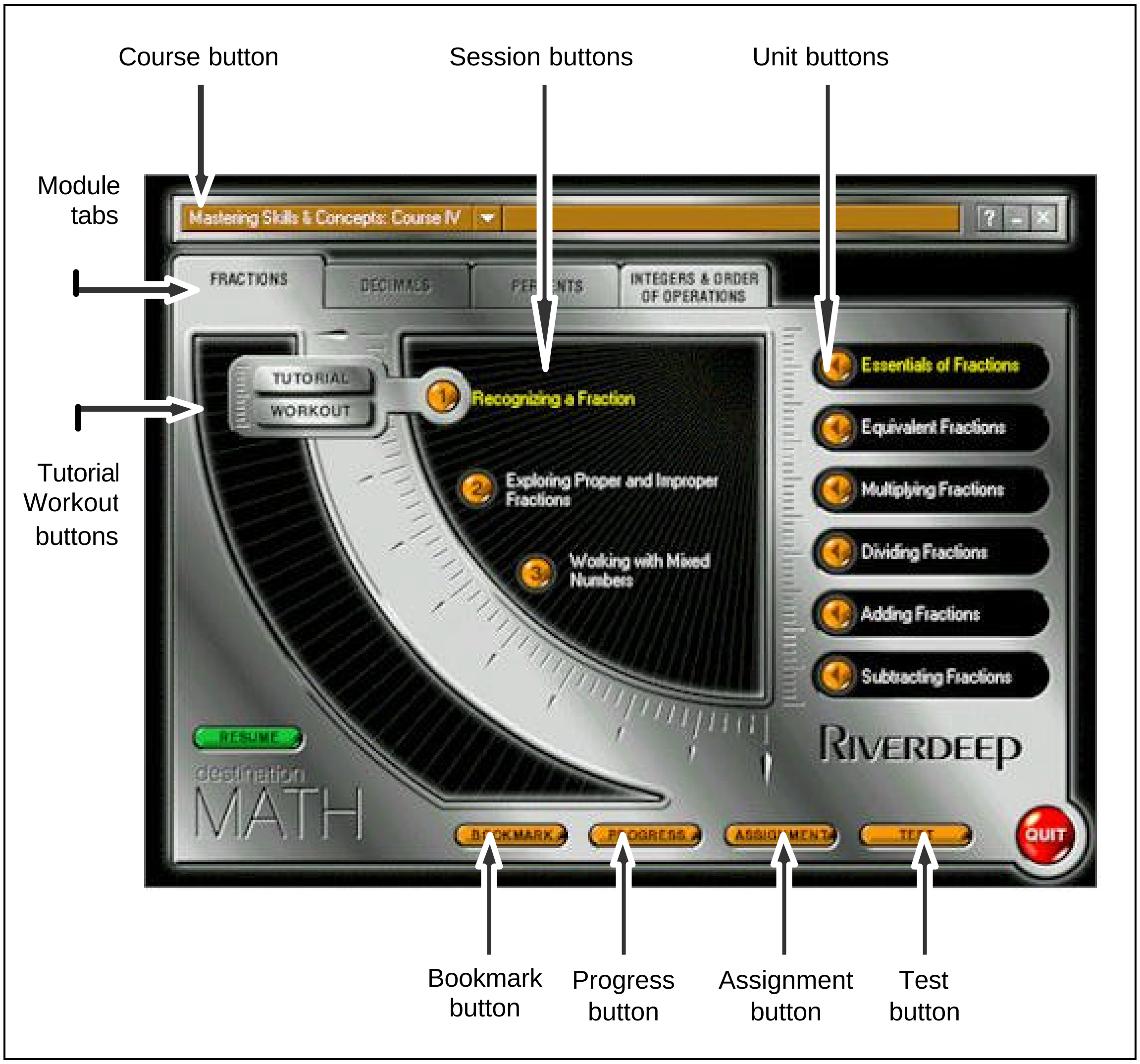
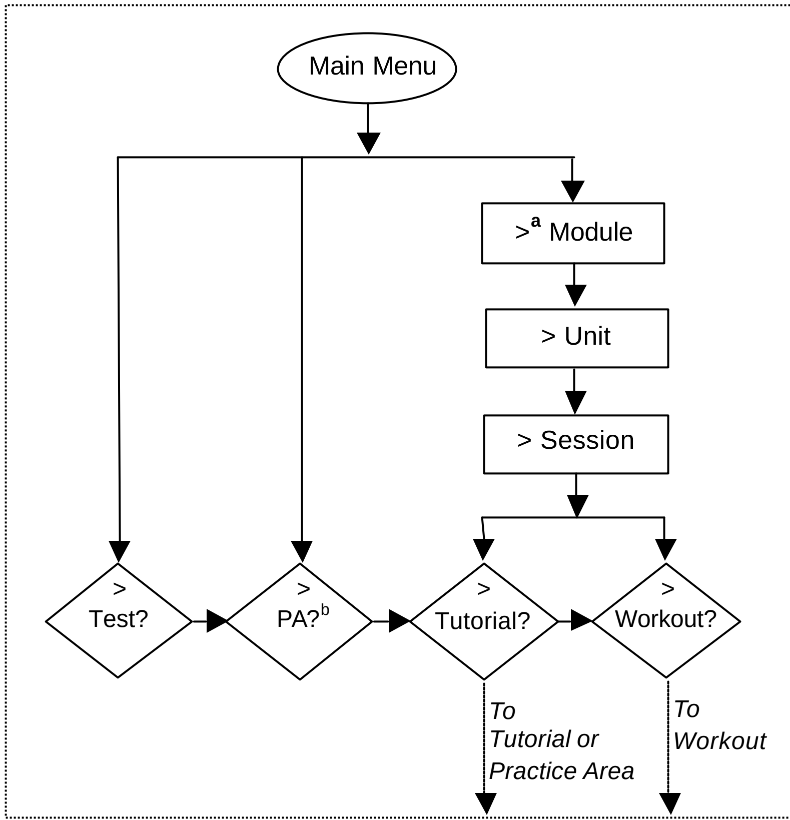


Figure 4. DM Main Menu Screen (Course IV)

Mrs. Hall chose to use DM Course IV, Mastering Skills and Concepts, with her Math 76 and Math 87 students. As shown in Figure 4, DM Course IV is composed of four *modules*: Fractions, Decimals, Percents, and Integers and Order of Operations, each representing a major topic in the eighth grade math curriculum. Each DM module is further broken down into *units*, which address specific learning objectives and are correlated with state and national standards for mathematics learning. (The unit buttons are context sensitive: they change based on the user's module tab selection.) The teacher management system for DM contains a bank of test items that are correlated with specific learning objectives, and organized by unit. Unit buttons for the fractions module are visible to the right of the user's screen in Figure 4. DM units are further divided into three *sessions*.

The user enters DM at the session level. Each session comprises a *tutorial* and a *workout*. The user may also access a tutorial or workout as a system-generated *prescribed assignment*, based on the level of mastery of learning objectives demonstrated by the user on assigned tests (Figure 5). The user progresses through a series of DM screens. Each offers navigation buttons for travel through the range of DM activity options. From the main menu, DM users may choose to work on a DM teacher-assigned test, a DM tutorial, or a DM workout. Figure 5 presents a procedural analysis of a user's possible activity selections from the DM main menu:



[a]> = Select

[b]PA = Prescribed Assignment

Figure 5. Procedural Analysis: DM Student Activity Selection

Teacher's Primary Experiences with DM

Test Editor

Mrs. Hall's first experiences using DM (in preparation for her implementation with students) focused on her use of the teacher-managed testing system. With Mr. Mercer's assistance, Mrs. Hall used the DM *test editor* in the teacher management system to create and assign student tests. She created each test by selecting test questions from existing DM test templates. The DM test editor lists questions for each learning objective within DM courses, modules, and units:

Researcher: So how did you create this test, Mrs. Hall?
Mrs. Hall: Eh, they give you a list of objectives, and then you click on them, you know to expand and tell you how many questions are in each, that's under the teacher management [pause]. I went by concept [learning objective], but it might be better to just select one thing, for like 26, or 16 questions. These, here were all under the same concept.

(CC, 3/6/2001)

Mrs. Hall created her first DM student test by selecting questions for learning objectives for the Essentials of Fractions Unit within the Fractions Module. A brief explication of Mrs. Hall's choices in creating this first test, inform our understanding of her implementation of DM with students.

For this first test, Mrs. Hall chose to assess her students' competence on three learning objectives, each with varied levels of difficulty. Table 8 denotes the learning objectives selected for her students' first teacher-assigned DM test, and the levels of difficulty and number of questions for each learning objective addressed in the test:

Table 8

First DM Test: Essentials of Fractions

Learning Objective[a]	Level[a]	Number of Questions[a]
Recognizing a Fraction	1	17
	2	2
Exploring Proper and Improper Fractions	1	21
	2	5
	3	3
Working with Mixed Numbers	1	15
	2	2
	3	2

Note. [a]Information provided in this column is provided for each math question selected from the DM Test Editor.

The sixty-seven item test, Essentials of Fractions: Part 1, was assigned to students by Mrs. Hall on their first day using DM in the computer lab. Mrs. Hall advised students who completed all test items to score the test, and begin their system-generated prescribed assignment of tutorials and workouts. The test was too long for many students to complete during the first class session. After this first class period, Mrs. Hall edited the test. She was unaware that her changes would replace records of student work for the original test. On their second visit to the lab, students were advised to retake the edited DM test, Essentials of Fractions: Part 2:

GS: I didn't finish my one [test].
Mrs. Hall: Well, we had to wipe that out. So you'll just have to do whatever's in there right now. Do what's in there.
JM But where's my test?

JF	Yeah. My answers are all messed up, too.
Mrs. Hall:	Yes. [Laughing] They all did. Just do the test that's in there. It's a different one that was in there, but go ahead and do it. This one's also on fractions.

(ON, 2/21/2001)

Mrs. Hall's use of DM for student testing increased steadily. The number of tests created and assigned to students by Mrs. Hall increased from two in February, to five in March, and eight in April. Table 9 lists all tests assigned to students by Mrs. Hall during their ten-week use of DM in the computer lab:

Table 9

DM Tests Assigned to Students by Mrs. Hall

Date	Test	Number of Questions
2/19/2001	Essentials of Fractions: Part 1[a]	67
2/21/2001	Essentials of Fractions: Part 2	29
3/1/2001	Decimals: Part 1	66
3/2/2001	Decimals: Part 2	35
3/15/2001	Decimals: Part 3	61
3/21/2001	Decimals: Part 4	25
3/21/2001	Decimals: Part 5	36
4/4/2001	Multiplying Fractions	34
4/5/2001	Integers: Part 1	41
4/5/2001	Integers: Part 2	42
4/5/2001	Order of Operations: Part 1	66
4/5/2001	Order of Operations: Part 2	35
4/18/2001	Geometry: Part 1	18
4/27/2001	Triangles: Part 1	18
4/27/2001	Triangles: Part 2	16

Note. [a]This test was edited by Mrs. Hall and re-assigned to students

Many students were unable to complete the DM tests assigned by Mrs. Hall in one class period. They frequently responded to Mrs. Hall's use of DM by voicing their objections to the length of the assigned tests:

JF: Look how many questions there are!
GS: Holy tractor! Look at all the questions!

(ON, 2/21/2001)

BS: The tests were too long. They took too long to do.
MG: Some of them were really long, like one was 66 questions.
(FGI 4/27/2001)

Students who were unaware that their incomplete test would not be saved by the DM system, realized that they must begin the test again during the next class session. Beth explained:

> But on the tests, if you're not done and you want to go see if you have any questions wrong, you can like score the test [pause]. But if you don't want to, cause it's not done, you have to do it all over [pause]. That's bad. Like the other day, I had like sixty-somethin' problems on there, and then the bell rang, and I had like 36 or something done, but then I had to come back the next day and do it all over.
> (SI, 4/5/2001)

> Brian groans loudly. The test items he completed on the current test during his last session have not been saved. He must restart the test. Likewise for CW.
> (ON, 2/28/2001)

Mrs. Hall expressed her surprise that DM did not save students' partially completed tests for later retrieval. She considered this a limitation of the DM system:

Mrs. Hall: You can score what you have done, but then you can't go back to work on it anymore [pause]. Because Beth quit [the test] and then she went back to see what it said, and the answer was zero out of 66. So that's an obvious flaw.
Researcher: I guess I'm [pause]. The only thing I can think of is that it [DM] may be designed for shorter tests.
Mrs. Hall: Possibly.
(CC, 3/6/2001)

During the implementation process, Mrs. Hall continued to use DM to assign tests (in addition to her regular assignment of Saxon tests), which were too long for students to complete in the allotted class time:

> Mrs. Hall begins the class again by taking a roll call. She introduces the four new tests to students: Integers Tests 1 and 2, and Order of Operations, Tests 1 and 2. Students moan their disapproval. Mrs. Hall tells students that these tests are shorter "just 25 questions or so, per test." When students begin the tests, they see that this is not the case. The integer tests each have 41 and 42 test items, and the order of operations tests each have 66 and 35 questions, respectively. Twelve of the 30 students who begin the integer tests cannot complete the test items during class time, and are advised to score an incomplete test. Some express disappointment with the low score received for their incomplete test.
> (ON, 4/5/2001)

In the fourth week of students' use of DM in the Gateway lab (week eight of this research), I asked students to respond in writing to the following question: "Was it a good day in the computer lab today or not? Tell me why." Fourteen of the 32 students who responded, spoke negatively about their experience with the DM teacher-assigned tests. One student wrote, "No! There are too many questions on the test. The subject we were working on was okay but there were just to many questions." Students contrasted their negative experience with the DM tests, with their positive experience with other DM activities (tutorials, workouts, assignments). Another student responded in writing that "today was a bad day in the computer lab because I failed another test. I do not like to take the tests because they are so long and I don't have time to take it. I also did the tutorials but they were cool." A peer explained, "Today was not a good day in the pc lab cuz i failed another test cuz I didn't get it finished like always i cant stand taking the tests but i can do the tutorials good." Students expressed their dissatisfaction with Mrs. Hall's use of DM to assign consistently lengthy tests. One student succinctly expressed her frustration with repeatedly taking DM tests which she could not complete during class time by writing, "And now i have to do my test over because we had to quit to do this. So now i have to do it over and that really stinks." Students negatively described their experiences with using DM to complete lengthy math tests.

On the first day I posed this question to students, Brian had completed 30 of the 61 questions for the Decimals: Part 3 test during class time. He quit DM without scoring his test, only to find out during the next DM math session that instead of completing the remaining 31 items, he also had to redo the first 30 items. Brian reiterated Mrs. Hall's suggestion that the DM system should include a mechanism for saving students' incomplete tests for later retrieval and completion:

> i took the test and didn't get it finished so now the next time we come over here i have to retake the test even what i already did i think that the program should have a save test thingymajiggy
>
> (Student Written Communication [SWC], 3/14/2001)

Tanya completed 34 of the 61 questions for the same Decimals: Part 3 test during class time. She remembered to score her work and received a score of 40% for her partially complete test. She expressed her sense of failure with the DM tests:

> yes I guess you would say it was a good day. Today i took the test for decimals part 3. I didnt get finished in time so i had to score my test at only question 30 so i ended up only getting a 40%! Which is a very bad score im not sure if it was because i didnt finish what i was doing or if it was because i got most of the answers wrong ill have to check that out tomorrow.
>
> (SWC, 3/14/2001)

Students continued to express their disappointment at receiving low scores for their unfinished teacher-assigned DM tests:

DF:	I scored it!
Researcher:	Great. How did you do?
DF:	Not too good.
Researcher:	Did you make 50%?
DF:	Yeah. Just 52, but I wasn't done.

KM:	Twenty nine percent, but I didn't get mine done.
JL:	I only got 32%.
Researcher:	But out of what you got done, you did 23 and you got 18 correct.
JL:	I guess I got 25 out of 32.
Researcher:	They're fine scores. So you're all set for your assignments tomorrow.

(CC, 3/6/2001)

Test Report

During this ten-week implementation of DM, many students were unable to complete the tests assigned by Mrs. Hall in one class sitting. Test questions not attempted by students were considered incorrect and factored into their final DM test score. Mrs. Hall expressed her confusion about how to use these reports of student performance on incomplete tests. She suggested that these test scores provided an inaccurate representation of students' math skills. For example, Mrs. Hall was unsure how she could use the test information generated by DM for AA:

> See here, it shows that there are 26 questions out of 60. So really she had, instead of twenty percent, 50%, because 13 out of the 26 that she got done were right. So I don't know what to do with this. I think I'll just start printing out for each student and then I'll see what it looks like for the completed problems.
>
> (CC, 3/21/2001)

Mrs. Hall noted that in general, her students were "not scoring real high on the tests to start with" (CC, 3/15/2001). For this reason, she said she was unlikely to combine students' DM test grades with their regular Saxon scores, to determine their class grade. When asked how she felt about students' learning using DM (local measures of assessment) Mrs. Hall said, "I think if they actually listen to the tutorials and try to work through it, I think they do offer good explanations of things, and so on. I think if they're approaching it and listening, I think they're learning" (TI, 3/21/2001). Mrs. Hall suggested that her students' use of DM might support their development of higher-order thinking skills in mathematics:

> It [DM] gives the students more freedom as to how they're going to approach something. So maybe that's good, they get to use a little more critical thinking skills, and I guess I have to get used to that, cause I guess, in mathematics we're always looking for the right and the wrong answer a lot of times everything's black and white in mathematics, although we're trying to get away from that now, with giving them more open-ended type questions [pause]. Even, cause they have some of those, even on the PSSA test [pause]. So I think the DM would support that very well, the actual thinking and the open ended eh skills.
>
> (TI, 5/2/2001)

Given Mrs. Hall's interest in ascertaining the level of cognitive activity her students engaged in while using DM, and her desire for appropriate metrics to replace the DM reports on incomplete student tests, I offered to assist Mrs. Hall by analyzing my transcriptions of students' verbal communications while completing DM test questions. To help inform our understanding of students' levels of cognitive engagement while working on DM math tasks, I used the classification of educational goals generally referred to as the *Bloom et al. Taxonomy* (Bloom, Englehart, Furst, Hill and Krathwohl, 1956). This taxonomy enabled me to analyze each transcribed student-attempted math problem, by identifying the *highest level* of cognitive activity demonstrated by the student during his or her recorded discussion of the problem.

In Appendix N, I provide a description of Bloom et al.'s (1956) six cognitive domain categories, with a corresponding list of specific cognitive activities demonstrated by students in Mrs. Hall's classes for each level within the taxonomy during their 10 week use of DM. I developed this core list of cognitive activities from my analysis of transcribed student-attempted DM math problems. I used this analysis tool in a consistent manner to analyze transcripts of student-attempted math problems. I provide five samples of coded student math transcripts (one for each level 2 to 6) in Appendix O. I organized the 200 analyzed transcripts of student-completed DM math problems by math activity: 156 test questions, 10 tutorials, 17 practice problems, 17 workout activities. Discussion of the results of these analyses are presented in Appendix P. I include the raw data for these analyses in Appendix Q.

Students' Primary Experiences with DM

Test Report

In contrast with their negative response to the completion of DM tests assigned by Mrs. Hall, students spoke positively about their use of the DM generated test reports following each test. Students who completed and scored a teacher-assigned test with DM also received their DM test report. This report would list the student's percentile scores for assigned (attempted and unattempted) questions grouped by learning objective. Students could evaluate their performance on the test by selecting the *user input* and *correct answer* buttons to compare their own answer(s) with the correct answer(s) for each test question. Beth described her experience:

> Well, one time I got a 99 [on a DM test]. On some tests I got 80s. On some tests I just did bad [pause]. But you can see how you did. It's easy! All you have to do is just go to tests, and then press what test you want to check, and then it will say something about "you answered these many questions" cause you answered all of em, and then you just say, "Score test!" and then it tells you what you got, and you can go back, and see what the answer should have been and stuff [pause]. That kind of makes ya try and figure it out, like, why you didn't get the right answer. It shows you the right answer. So you know how to do it, like if it was on a test or something.
>
> (SI, 4/5/2001)

One student suggested that "when you know what that answer was, then you can do better on the next one cause it can save you making mistakes" (4/5/2001). Another student noted that using the test information helps her "feel pretty good about it [the test]" (2/22/2001). As ME reviewed his test report for the Integers: Part 1 test, on which he scored 54%, he noticed that he scored higher on certain learning objectives than others, and began to speak more positively about his test performance:

> ME: Fifty-four percent; I thought I did better than that.
> Researcher: What does that [review test] information tell you?
> ME: I guess I didn't do too good. I don't know [pause]. But, I mean, 69% for this is pretty good [pause]. What was that for? Oh, em [pause]. Hold on [pause] adding absolute values, and for eh using the number line to add two integers.
> Researcher: And here you got 22 out of 22. What's that for?
> ME: Exploring absolute value [pause]. So I guess I did pretty okay here. So I can just going to go to prescribed assignment.
> Researcher: It looks like you're all set.
>
> (CC, 4/5/2001)

There were just 12 questions on the Geometry: Part 1 test assigned to students by Mrs. Hall in week 11 (week 7 of the DM implementation). Students had ample time to complete the test in class, review their test report and work on their prescribed assignment. Brian, CW and Chris used the test report and test review options to appraise their performance on this test. They concluded that greater care reading the questions would increase their future success with DM tests:

> CW scores 75% on his completed Geometry: Part 1 test. Brian, who sits next to him, scores 84%.
>
> CW: I got 75%! I can see the ones I got correct. [Selecting the user input and correct answer buttons] Oh, man!
> Brian: A right angle is 90 is it not? What the [pause]. Ah, they wanted more than one [answer]. I didn't do that!
> CW: Here they wanted two answers, I didn't know that!

Researcher: What didn't you know, CW?
CW: That they wanted two answers for this one. Select your answers. We'd have got a hundred if we'd seen this!
Brian: There are two here when they wanted more than one answer. I need to read more of this report.
CW: Still 75% [sounds pleased].
Researcher: That's a fine score indeed.

(CC, 4/18/2001)

Chris has just completed the test, Geometry: Part 1. He immediately selects the score test option and receives 67%. He sees that he missed 4 of the 12 test questions.

Chris [Selecting the *user input* and *correct answers* buttons to review question 1] Oh no! And the parallel lines don't ever meet, so it would be that one and that one. I can check the correct answers [pause]. Ah! [Reviewing question 2] Which of the following statements is always true? Ah, that one's not true because in a rectangle [pause]. Ah, I didn't think of that! [Reviewing question 4] Which of the following defines the angle? B it's just plain B. Oh no, it's both of them! Select your answers! Ah no! [Reviewing question 6] And this should have been the vertex. I didn't think of that one.
Researcher: You did well, Chris.
Chris: I guess I didn't do too bad, but I need to read the questions [laughs].

(CC, 4/18/2001)

Tanya used her test report for the Integers: Part 1 test to evaluate her math strategies in answering the test questions:

> For [question number] 27, I had 73. The answer was one point seven three [pause]. I couldn't figure out what they [counting numbers] were supposed to be [pause]. Oh, why did I do that? Oh! I don't know why I did that! This one was easy, from least to greatest. What did I put? [Locating her own response] What the heck! I put them from greatest to least! [pause]. For 38, six point one. Oh, I didn't divide! I never found the average. I was supposed to divide by 10! And I bet that's what happened in the last one as well! Now this one is six, negative six. This is positive, this is negative. So how is it equal? [pause] Oh I didn't times it when I got the number!
>
> (CC, 4/5/2001)

<u>Prescribed Assignment</u>

Each student who managed to complete and score his or her DM test within the allotted class time, received a DM prescribed assignment. The DM prescribed assignment contains a system-generated set of DM tutorials and workouts allocated to the student based on his or her performance with learning objectives selected by the teacher, and presented in the DM test. During their second visit to the computer lab to use DM, Mrs. Hall explained the use of the prescribed assignment to two students:

Mrs. Hall:	Now you need to go down and click on prescribed assignments.
JM:	Is that a menu?
Mrs. Hall:	It will give you problems in those areas that you need to work on. And it also has tutorials. [To GS who has selected prescribed assignment button, as instructed] Yes. Now go and click on this [pause] and then go back to the menu, and now you can work on your assignment.
GS:	Wow [sighs].
JM:	[Looking at his test report] What are we [pause]?
Mrs. Hall:	These are a couple of things that you had zero percent on in your test. [JM laughs nervously.] And so that's what they gave you to work on.

(ON, 2/21/2001)

Students who had sufficient time to complete and score their test and begin their prescribed assignment during week eight of this study (week four of the DM implementation) write positively about their experience with DM:

> Yes it was a good day in the computer lab because i learned a lot today. Decimal test 3 i got a 65 on it but i saw what i did wrong, i think that is a good program for kid to get used to learning math i did all of my assignments to day i passed them all
>
> (SWC, 3/14/2001)

> Yes it was a really good day in the lab. We done deciamal test three. We done some assignments. It was fun. I passed all of my assignments. I did not think that I could do that good with division.
>
> (SWC, 3/14/2001)

> Yes it was a good day in the computer lab i learned a lot of stuff today. i got alot done today it was a good day. I got a 71% on my test then i did some of my work to.
>
> (SWC, 3/14/2001)

> I did decimal test part 2 and i did really good on it. And i did my assignments for test 1 and got them done it took most of the pd. to do my test 2 it was fun i can't wait till the lab tomorrow
>
> (SWC, 3/14/2001)

<u>Tutorials & Workouts</u>

The full range of DM tutorials and workouts (including those contained in their prescribed assignment) are also accessible to users from the main menu. Students in Mrs. Hall's class did not receive whole-group instruction on how to use the DM buttons on the main menu. Many students navigated the various DM activities by finding their own way in the system as Brian did:

Brian:	[Selecting the tutorial or workout option button within the decimals module tab] What's this?
Researcher:	A tutorial is like when they teach you something, and the workout is when you try some of the related problems.
Brian:	What should I do?
Researcher:	What do you think, yourself? Did you do all of your prescribed assignments?
Brian:	I think. [Brian selects the prescribed assignments button and sees that his assignments are complete. He selects the Essentials of Decimals unit, Investigating Decimal Place Values session and opts for the tutorial] I can do this!

(CC, 3/21/2001)

Using a DM tutorial for the first time, DS and JC mistakenly assumed they should complete the math problem presented, before continuing the tutorial. They discussed the problem-solving strategies and worked out the answer together (finding missing multiples for six) excitedly interrupting, contradicting and agreeing with one-another. They then chose to continue the tutorial, which led them through the problem solving process in a step-by-step manner. Although they had prematurely completed the math problem, both students claimed to have learned from the step-by-step tutorial, which had ensued:

> Tutorial 2: Adding Fractions
>
> JC and DS view the first screen in the tutorial, and mistakenly assume they must complete the problem, before proceeding to the next screen.
>
> Researcher: You guys were really fast. Did you learn anything from doing the tutorial, even though you had the answer worked out early on?
> DS: Well, I guess I already knew what multiples were, but not really good. It helps to do this. And eh, and like, how you get it. Like three, or eh, two thirds, and you take five-fourths, and I never really knew how to do it, that bit [pause] how you got the 12.
> Researcher: Did you learn anything, JC, by going through it?
> JC: Eh, I don't know, not really [pause]. Eh, yeah. I didn't know about the common denominator, but I knew the common multiples.
> Researcher: [As I'm getting up] So what do you think of this way of doing math?
> JC: It's pretty cool. I like the story.
>
> (CC, 2/21/2001)

<u>Scenario Problem Context</u>

All DM Tutorials and Workouts present math concepts to students in scenario or story format. Mrs. Hall explained that the tutorials and workouts offered students more realistic contexts for learning than the traditional math text:

> Well, the Riverdeep, the system, what we're already using does like, offer more real-world type situations. And I think that's good, because the students often have difficulty seeing where they use this. They ask, "Where do you use math?" and I try to tell them, all the time, like in everything. But sometimes they just don't see that [pause]. I just think they need that, a lot more math in real life.
>
> (TI, 3/28/2001)

Chris agreed that math concepts are embellished when embedded in an interesting and realistic story:

Chris: Em, in the computer lab, they em, the one thing was like, I forget, what the guy [pause] but he wanted to buy a stereo and he only had so much money. That's more real-life, because you know, people buy stereos and they have to have a limit on how much they can spend. And the [math] book does that too, for some [questions] but then they don't.

Researcher: Do you think that those scenarios, or stories helped you see the importance or relevance of math?

Chris: Yeah. I guess the story problems are more exciting over there. Cause, like, I'll use the old 2+2, I guess [laughs quickly]. Say you just had two plus two and that's four. I guess it's more exciting when you have, like, two people went to a concert and then another two people went to a concert, so how many people were there? I'd say four. So I guess, reading the things might help it more, or I guess, it just makes it more fun.

(SI, 5/2/2001)

KM was especially interested in how he might increase his pocket money while estimating profit gains for selling lemonade:

Decimals: Part 2, Question 19:
Karo and Tarisha are selling lemonade. On the first day, they make $189.55. If the ingredients cost $39.15 and the advertising flyers cost $9.60 which of the following is a reasonable estimate of their profit?
Select your answer.
$159 $230
$109 $140

KM: [KM is incredulous] A hundred and 89 dollars and 55 cents for selling lemonade! Jeez! So the ingredients cost 39 dollars 15, and the advertisement flyers cost 9 dollars 60 [pause]. So which of the following is a reasonable estimate of the profit [long pause]. This is their profit, right? That's how much they made the first day, so that must be profit? [pause]. Jeez, for just selling lemonade!

(CC, 3/6/2001)

Explanations

Students frequently expressed their liking for the step-by-step explanations embedded within these scenario problem contexts. One student said, "If you didn't understand the questions of em, they would explain it out, instead of just giving you the answer" (CC, 3/15/2001). Another student added that the DM explanations also showed him *how* to do the problem: "It helps you, like if you don't understand it, it tells you how to work it out" (CC, 3/6/2001).

Researcher:	So how do you feel about your math learning, using DM?
Chris:	Well, they explain it, step by step.
BR:	Those tutorial things are nice, cause they, like, explain lessons and everything, cause you don't have to read em for a change. I think I get more out of it that way, than just reading it by myself.
BS:	They make it, you know, so that if you don't understand it, they'll go over it.
DS:	They explain it, like in detail.

(FGI, 4/18/2001)

KM:	I liked DM because it helped me with what I didn't know.
Beth:	It showed ya how to do stuff.
DS:	Well, it explained it all out for ya. And it showed ya how they did it, like she just said. So ya got to learn it.

(FGI, 4/27/2001)

Chris talked about his use of DM explanations to learn about repeating, non-terminating decimal numbers, and to multiply decimal factors:

Researcher:	What do you think about the math you've been learning here in the lab using DM?
Chris:	Eh, it's pretty easy. Cause they, em, explain it to you pretty well, and then you know what you're doing better than you did before you came in, and actually did it.
Researcher:	Can you think of any example of that? Any example of something you learned here, that you didn't know as well before?

Chris:	Eh, like, I know *Pie* is three point one four and whenever they were showing the circumference of a circle and stuff, they actually showed the whole number. And so, that's something I learned, although I don't remember the whole thing of it.
Researcher:	Were there other times you learned something in math using DM?
	Lots of times, like in the one decimal thing, eh, I forgot for a while because we haven't been doing it. It's whenever you multiply, and then you have to take up the numbers at the end, from the whole, after your decimal point. You can times those up, and then you [pause] it tells you how many spaces to go. And I was going the wrong way the whole time. So I finally caught myself on doing that. You go, to your [he waves his arms] to there [pause] from right to left. There we go, and I was going from left to right.
Researcher:	So you go from right to left, when you do what now, Chris?
Chris:	Em, putting the decimal point in when you're multiplying numbers, eh, decimal numbers. I was going from left to right, instead of right to left, and that's probably why I was screwing so much up. Eh, like, I forget what it was about but they [DM] gave us the numbers but they didn't put the decimal point in, and in here, I put it wrong. And then the next day, Brian put it wrong, so I was able to help him with that.

(SI, 4/5/2001)

Beth described her poor understanding of fractions in the past, and her use of DM explanations to learn to multiply and divide fractions:

Researcher:	Is there anything that you do like about math, like a particular type of problem or a particular way to do something?
Beth:	Em [pause] not really. Eh, maybe fractions [pause] like adding and subtracting them.
Researcher:	Any particular kinds of problems that you like in math, more than others?
Beth:	[In a low voice] I like the easy adding, subtracting stuff!
Researcher:	Did you do anything here with DM, which helped you understand math?

Beth: Well, with fractions, I didn't really know it, and my mom got me a tutor for it last year. And like, it helped on here. It helps you [pause]. It explains it more and it helps you like [pause] get to know what to do and stuff better, than over there. Because when we didn't go to the computer lab, we just sat in the room all day and did problem sets, like [pause] and stuff, and I really didn't know how to do fractions. I had problems with them.

Researcher: So how do you feel about learning fractions now?

Beth: I have [pause]. I don't have very much trouble dividing them now. And like with multiplying fractions, I thought you'd do the same thing like you do with dividing, but you don't. You have to [pause] like dividing fractions you do the three steps or whatever, but with multiplying you do just the two.

(SI, 4/5/2001)

<u>Multiple Representation Formats</u>

Students found the audio presentation of problems in DM especially helpful. One student commented, "I think it [DM]'s good because the voices explain, you know whatever you're in." Another explained, "I like that I don't always have to read everything. The problems are hard to do, but you can hear them one step at a time, if you need help or whatever." A third student declared, "You understand things *way* better when you're hearing somebody say it than when you're just reading!" Brian agreed:

> Well, at the very beginning, the thing reads it for you [pause]. It's better because you have the speaker sayin' it too, so alls you got to do is listen. And then there's that repeat button, an' it was easier to follow when I could hear it an'see it over.
>
> (FGI, 4/27/2001)

One student thought there was an excessive use of audio in DM and to compensate, he devised a simple strategy (to turn down his speakers). His sentiments were not echoed by any other student.

Researcher: Well, JF, what do you think of this?

JF:	I think it talks too much.
Researcher:	How come?
JF:	Cause it explains everything before you can get a chance to get it wrong.
Researcher:	Ah. How would you like to change that?
JF:	I don't know, I just turn the speaker down [pause]. It'd probably be different with headphones.

(CC, 2/28/2001)

Brian frequently spoke about his liking for the DM voices and also for Dijit, the main character. He insisted, "That Robot's pretty cool… Oh, yeah. When one guy says, what's it [pause] 'Dij!' I love how he says it!"(CC, 3/28/2001). Another student suggested that without the animated characters and voices, DM would be nothing more than traditional instruction, "The cartoon characters! I love that they use them because, like, if they didn't like show the little guy [Dijit], walk out there and start talking to you, it would feel like a lecture" (CC, 4/19/2001). Beth and others also liked the voice-overs and commented that they were particularly appropriate:

JC:	Yeah. I like DM it's like, "Hey, Dij!" and stuff like that. That's cool.
Beth:	Yeah, I liked it a lot.
DS:	Eh, the voice isn't monotonous. Like not boring, that steady, boring thing. But it was good to listen to [pause]. Easy to listen to.
AA:	And not boring, or stupid.
JR:	Kind of smart.

(FGI, 4/27/2001)

It makes it more interesting. Well the guy talks to you. He'll talk to you and help you how to do it, and stuff [pause]. And the voices, they're [pause] they're not like [pause] they say it in a fun way, not like in a serious way, or like a baby way.

(SI, 4/5/2001)

Dijit's appearance also rendered him popular with the eighth grade students, "And the guy in it, he has orange, square shoes and stuff, [laughs] and it's funny lookin'!" (CC, 4/19/2001). Chris added:

> I think that if, like [pause] the graphics in DM are actually pretty good. I think that, like people will pay more attention to 3-D graphics than boring graphics. Cause like if you have something that you see there that catches your eye, you actually want to do it.
>
> (FGI, 4/27/2001)

Tanya suggested that the visual representation of math concepts also supported her understanding of math concepts:

> They give you a lot of pictures and stuff that probably help. The one sheep thing, like when he was cutting the wool off the sheep to make the things, they had the little sheep in the little circle. Then they colored the circle that had the cut sheep, and they showed you the fractions for how many cut sheep there were to the whole bunch. So, that's probably a picture that I found helpful to use. Besides trying to figure the thing out in your head, you have it right there on the computer screen, you can just count it, one by one.
>
> (SI, 4/4/2001)

<u>Repeat Option</u>

Brian spoke about his use of the repeat button in DM tutorials to focus his attention on the audio presentation of word problems, which were his least favorite type of math:

> Researcher: If you were to think very hard about something you do like in math, what would you be thinking of?
> Brian: Well, I would say, like the [pause]. The harder questions I find I like em better, cause I'm like, I can't do word problems. So anything that's algebra, or something. I can do some trigonometry.
> Researcher: So what would your favorite type of math problem look like?
> Brian: It would not be a word problem.
>
> (SI, 4/4/2001)

Multiplying Decimals, Question 3, Workout 3

Researcher:	How are you doing there, Brian?
Brian:	I'm trying to figure out the length here, but it doesn't give it.
DM:	If the volume of a rectangular prism equals length times width times height, calculate the volume of the mould in cubic meters and express your answer to two decimal places.
Brian:	I can't find the volume of it without the length!
Researcher:	Did they forget to give you that information?
Brian:	I don't know. Eh [Brian scans the problem then presses repeat.]
DM:	Maria wants to make a concrete base for her sculpture. This mould for the base of her sculpture is a rectangular prism whose length is equal to the sum of its width and its height. If the volume of...
Brian:	[Interrupting] Ah! So I got to add em together for the length.

(CC, 4/27/2001)

Brian felt that his continued use of the repeat option in the DM tutorials and workouts had improved his ability to analyze math questions:

> I find it hard to do the story problems. I think I got a lot better at em, in the lab. I just kept on doin' and doin' them when the thing would give em to me until I finally got em down. Because before when I'd do em out of the book, I just [pause] I can do em, I just keep, well, I have to read that little paragraph thing there and I always get lost.
>
> (SI, 5/2/2001)

Brian was also pleased with his decision to use the repeat button and not the show me button, when he struggled with math problems in DM:

Researcher:	So do you use the show me option often?
Brian:	I usually don't use it. If I can't figure it out, I just try it again [pause] repeat it [pause] cause I get lost in it all, and then I have to keep re-hittin' the replay [repeat] button to figure out what it was sayin'. So the repeat, eh, it's pretty helpful. You get to the end of whatever and finally answer the question. Yeah, I like that there.

(SI, 4/4/2001)

<u>Practice Problems</u>

With their increased use of DM, Mrs. Hall's students gained in their understanding of the DM activity system. Students frequently chose to use the optional practice area learning environment to demonstrate their understanding of math concepts taught in the preceding tutorial. One student rationalized her selection of the practice area problems following the tutorials as follows:

> And like, with DM, you can just go to the next lesson, when you finish something, because it gives you the practice problems, so you know, it makes sure that you know what you're doing, and then, you're not trying to mess around with the problem just to get it done.
>
> (FGI, 4/27/2001)

Another student suggested that DM enabled her to consistently complete all of her practice problems: "I liked the DM because it helps you. It helps you at your practice problems, and how you work and it makes you learn faster at getting them done" (CC, 4/4/2001). Tanya always completed the practice problems within her Tutorials:

> Essentials of Fractions, Tutorial 3, Practice Area
>
> The second bell rings and students begin to leave. Class is over. Tanya notices that only a few students remain, and rushes through her last two practice problems. She receives her score: three out of four questions correct, before hastily closing the program and logging-off the computer.
>
> Researcher: So what did you think of what you were doing today?
> Tanya: It made things easier to understand, I guess.
> Researcher: Why did you decide to do the practice problems. Weren't those four practice problems optional at the end?
> Tanya: That way I would understand more. That way I could learn by doing the problems. They're still difficult. But the practice was good.
>
> (CC, 2/21/2001)

Show Me Problem Solutions

DM Workouts also present math problems (again, in scenario format) that test students' understanding of math concepts learned in the preceding tutorial. The *show me* button allows the student to view, in sequence, the solution to the workout problem. One of Mrs. Hall's students explained, "I think it [show me button]'s good, cause if you don't understand something you can click on *show me*. I really liked those" (4/18/2001). Another student claimed, "it [DM] helps you with your problems and if you don't know how to do it, they'll actually show you how to do it!" (4/18/2001). Chris liked to use the show me option because it showed him, in sequence, the steps for how to solve a problem: "Like, if you're given the practice problems during a tutorial, you could say, 'Show me,' and it shows [pause] it shows you how to do it, step-by-step" (3/21/2001). Chris explained that, when the timing was right, using the show me button was often a less frustrating and more efficient alternative to struggling with the math problem:

> Well, in here when you do a problem and you get it wrong, you can keep trying for it. So like you get so frustrated that you don't want to do it any more, you can have it so you don't have to do it anymore. You can ask it to show how it's done. Because it's better than just giving the problem, and then to keep getting it wrong. Cause that also takes up a lot of time to do it.
>
> (SI, 4/4/2001)

Beth also spoke positively about her experience with DM workouts, in particular the show me option:

> Beth: In the workout or whatever, you just like have to do it, and if you get it wrong like, I don't know, they [pause] either [pause] there's a thing that says, "Do you want to try it again?" or you can select a show me [button] and it will show you how to do it [pause]. Like with fractions, they showed you how to do em.

> Researcher: Ok. And what did you think about the way they showed you?
>
> Beth: It shows you *completely* how to do em. It just says this is the problem and how to get the answer, and anything like that. It just explains it out clearly and to help you out [pause]. It helped you out like to learn it better.
>
> (SI, 4/5/2001)

<u>Tools</u>

The DM calculator tool is accessible to users on any DM screen, including DM tests, unless deactivated by the class teacher or administrator. Mrs. Hall's students used the DM calculator to perform various routine computations:

> GS: [Reading the problem] Round to the nearest hundredth [pause]. I need a calculator. [GS accesses the calculator from the side bar on the monitor. He divides one by three and gets the repeating decimal three.]
>
> Researcher: So what are you doing now, GS?
>
> GS: Using my calculator to change the fractions into decimals. This is three tenths. The nearest hundredth is...
>
> (CC, 3/21/2001)

KM noted that with the calculator he could do the DM problem "more easily than simply trying to do it in your head" (CC, 3/22/2001). Students frequently used the calculator to evaluate their own mental computations:

> JL uses the calculator to find the product. He begins to type the number in the answer box, and then checks this number with the answer found on his calculator. He corrects the number in the answer box, and proceeds to the next question.
>
> (ON, 3/22/2001)

Chris used also used the calculator to evaluate his own mental computations. The coded transcript excerpt in Table 10 describes Chris's uses of the calculator while performing DM math problems:

Table 10

Coded Transcript of Chris' Use of the DM Calculator

Decimals: Part 2, Test, Question 9

Ebony is taking down a computation. The digit in the hundredths place in the first decimal is smudged and can't be read. If the computation is

26.0?7 + 16.173 = 42.2,

what is the value of the missing digit?

Type in your answer

Transcribed Text	Calculator Use
And then [pause]. Well to see if that's right, I could go over here, to the calculator, and put in one o two point five four eight, plus 13 point the number I think it is, three, five. [Andrew deletes the sum on the calculator, by mistake, and starts over] One o two, point five four eight, plus one three point the number I think it is, three, eight two.	To assess calculations performed mentally
And if that's right, I should get that answer right there. And so it's not right. I must have done something wrong.	To assess a logical prediction or estimation of the answer.
I was off by one point on this, and so I need to add one, because it was fifteen instead of sixteen, so I'd probably add, it would be four, then…	To rethink the problem strategy or plan

Note. Excerpted text (CC 3/21/2001)

Some students preferred to use the hand-held calculator, than the DM calculator on screen. BM explained, "I find this one [personal calculator] easier to use, cause I don't have to keep pulling this thing [DM calculator] up" (2/28/2001). AH noted that using the DM calculator "takes up more time" (2/28/2001). Mrs. Hall suggested that some students might prefer using certain tools, and that their preferences might become habitual in either the regular math class or the DM math class:

> I think that they've maybe become creatures of habit too because you hear some of them asking for paper and pencil. And even though there's a calculator available on screen, some of them will take a calculator with them to use rather than that one [pause]. I guess, just because they're used to using it maybe, or some of them don't like to use a calculator at all, either here or in the lab. So I'm not sure, if they really use all the tools available to them in either place.
>
> (CC, 3/28/2001)

Two students consistently brought their own paper and pencil to the lab, to supplement their use of the DM learning system:

> JF is writing on an A4 sheet of paper, only partly visible from beneath his keyboard.
>
> Researcher: What are you at there, JF?
> JF: Oh, just [pause]. I can't use the calculator there. I just like to work it out like this. Eh, I just like to see it.
>
> (CC, 3/28/2001)

Students often demonstrated their need for pen and paper when working on math problems to document or memorize calculations in multi-step problems.

> Researcher: So how are you doing here, BM?
> BM: [BM's verbal calculations, etc. are inaudible. She reaches for her pencil and paper and explains, laughing] Oh I'm just writing it down, to not forget it.
>
> (CC, 3/6/2001)

> [Chris is finding the circumference of a circle.] Eh, that's just two sides. You have to add up all the sides. So I'd take this and I'd times it by two, and I'd get that number, two four point seven. Without anything to write on, I hope I can remember that. And then I'd times seven [pause]. And you know I don't [remember] already [laughs]. So I'm just going to add these all up [pause]. Five plus one two point three five, plus seven point o five, plus seven point o five equals 38 point eight.
>
> (CC, 3/2/2001)

> AH: Why don't you just like minus two point one minus one point eight?
>
> Tanya: Wait, Marcus came in [pause]. Ok. Then you take 12 point two eight plus two point one, so this was his time. And then, subtract that from whatever the school record was. Oh, em, what was it? Do you have it, AH? [Tanya looks on her piece of paper, and realizes that she didn't note it. She reworks that part of the problem.] That's what I got. So that's the school record right there, ten point four eight. Write that down! [AH writes on the scrap of paper left behind by a student in the previous class.]
>
> (ON, 3/6/2001)

Students also learned about computer tools incidentally while using DM. The tools of the system such as shortcut keys, keyboard functions, etc. became transparent to students over time:

> Researcher: What are you doing there?
>
> TD: Using my keyboard.
>
> Researcher: Is that working for the calculator? [TD nods.] How did you figure that out?
>
> TD: Huh? I just did.
>
> (CC, 3/6/2001)

> AH asks Tanya how to do the current problem, and she pauses momentarily, simultaneously depresses the control, alt, and delete buttons on the keyboard and then assists her friends.
>
> Researcher: What are you trying to do there, Tanya?
>
> Tanya: Oh, just pausing it [pause]. That way the time stops.
>
> Researcher: How do you pause it? By using control, alt and delete?
>
> Tanya: Yeah.

Researcher:	[Laughing] How did you figure that out?
Tanya:	I em [pause] well [pause] I'm used to pausing games and stuff. I eh, just tried it.
Researcher:	And why do you think that matters?
Tanya:	I don't know, I didn't know if they even use your time in here, or if they just keep track of time.
Researcher:	Just keep track, but it doesn't interfere with your score.
Tanya:	Oh, I see. Ok [laughs].

(CC, 3/6/2001)

<u>Progress Report</u>

DM users can review a description of all their completed work at any time, by clicking on the progress report button. Mrs. Hall was unsure how to use this progress report information to assess students. In the eighth week of a nine-week grading period, she began to print out and review both reports for each of her students. Discussing AA's progress report with me, she commented that AA "doesn't seem to be very far along." Tutorials were described as 100% complete, even though AA did not correctly complete all question items:

> But they don't have to do the show me [option] if they have completed the questions. So this is considered completed even though she had only one out of four questions right, because she had one right and two wrong, and one she didn't do. So I think that's what that hundred percent means. It's just that she's gone though it. It's going to show up as 100% complete but they may not even have any questions correct. So that's why I don't know how to use this information.
>
> (CC, 3/21/2001)

BR suggested that the progress reports might "be good for the teacher to see if you're just goofing around" (18/4/2001). He liked to use the progress report to navigate or direct his own learning: "To us I guess it's good cause you can go back to the practice problem you wanted to do next." MG discovered the DM progress report at the beginning of the class session, in week 11 of this research (week 7 of the DM implementation). He used the report to identify his incomplete assignments, and decided to focus on the four not attempted practice problems for the unit, Essentials of Fractions. At the end of the lesson, MG was pleased with his use of the progress report to manage his own learning:

> Researcher: Well, MG, how did you get to this? Was this on what you selected?
> MG: Yeah, I just kept going.
> Researcher: Great.
> MG: I'm doing everything and getting everything squared away [sounds pleased].
>
> (CC, 4/4/2001)

Tanya also used the progress report to identify gaps in her progress with DM. Her incomplete assignments included some not attempted and incorrect workouts for the units on Essentials of Fractions and Essentials of Decimals. She also had some incorrect and unattempted practice problems, and an incomplete tutorial for the unit, Dividing Decimals. She chose to make-up work on Essentials of Decimals, and navigated her way back to the workout, to resume work:

> Researcher: So what are you up to there, Tanya?
> Tanya: I'm going to my progress report to see how I'm doing. [Tanya silently reads her report.]
> Researcher: Do you think you can use that information?
> Tanya: Well, I'm not sure, because I don't think I can change anything.
> Researcher: Well, your report is updated every time you work on DM, so it will record any new work you do.
> Tanya: Oh. I didn't know that. So it's not like the test [pause]. I have a lot of not attempted stuff here. So I could go back and do those [pause]. *Not attempted* and no *show me* [pause]. But I don't know where it's at. [Scrolling up the page] Wait now [pause]. Essentials of decimals, investigating decimals. Was that a tutorial or workout? Hmm. Ok, ok, I have it.
>
> (CC, 3/29/2001)

Beth also used the progress report to evaluate her own performance using DM. She noticed that there were minor and more significant gaps in her progress. Examining the progress report enabled her to identify the learning objectives she should focus on in future activities:

Researcher:	Is there anything there to help you decide what to do next?
Beth:	I can see what I got right and what I got wrong.
Researcher:	Can you use that information?
Beth:	It can show me how to do it [pause]. Em, you can like [pause]. You can see the questions like and em what you got on them, and if they're incorrect you can go back and do em over. I could do that workout over.
Researcher:	You only had one incorrect question on that one. How are you going to figure out where you need the most help?
Beth:	[Beth scrolls down the page.] This one here. I got that one wrong and I didn't even do that one [pause]. Eh [pause]. finding the volume of a [pause]. Eh, that's in Multiplying Decimals. [Beth navigates her way back through the menu and on to the intended workout.]

(CC, 3/29/2001)

Many students who used the progress report to regulate their own learning expressed their belief in the authority of the information conveyed by DM in the progress report:

Researcher:	How are you doing there, DS?
DS:	Alright
Researcher:	How are you going to use the information there?
DS:	Just go ahead and try and do it again [pause] see if I can get it right.
Researcher:	So which ones will you focus on?
DS:	Here I haven't even attempted this [pause]. I mean, the biggest one I have problems with is the fractions. It even says so here. So I'm going to work on this one.

(CC, 4/4/2001)

Activity Choices

Students were initially surprised to learn that if they completed Mrs. Hall's DM test during the class time, they could choose their own DM math activities, beginning with the DM test-generated prescribed assignment. Mrs. Hall explained, "I think they're used to having everything planned for them, and not used to making these decisions."

CW:	What are we to do?
Researcher:	You choose. You can either do the workout or the tutorial.
CW:	Oh.

(CC, 3/21/2001)

Beth told me that it took her some time for her to become familiar with the full range of activity choices for math offered by DM:

Researcher:	How well do you think you can get to where you want to be by using the different buttons [pause]. If you want to do something, do you have difficulty getting there?
Beth:	Eh, well, at the start it's a bit difficult, because you don't know how to do all of the stuff, like you want to do it all, but some of the things you don't know how to. So [pause] like you learn to get the moves down.

(SI, 4/5/2001)

When students became familiar with the features of the DM and could use them purposefully to access the range of activities offered by the system, they began to contrast the choices available to them in the DM math environment with the limited choices in the regular math classroom. Brian noted that in contrast with her regular math class, Mrs. Hall had given students the opportunity to make choices in the Gateway lab, and determine (to some extent) the activities they would pursue with DM. He commented, "I like how she just lets [pause]. Like she'll give us the general area to go, and then she'll let us do whatever, or like if we have to do the tests, we can do some worksheets first"

(4/18/2001). Beth compared the range of activity options available to students using DM with the few choices students had in the regular math classroom:

> Beth: Over there [in the computer lab] you get to pick what you want to do, and not what she [the teacher] wants you to do.
> Researcher: So what kinds of choices did you have, or did you make with DM?
> Beth: Em, that tutorial thing, or the workout [pause] you got to pick either one. Or if you wanted to do a test that day, or if you had a prescribed assignment, like it would just give it to ya [pause]. It [DM] shows you, like it tells you stuff about it [math], and then it gives you a problem, and if you aint got it right, you can either try it again or you can click a little button and it will show ya how to do it an' stuff. You get to do stuff on your own. It explains it for you instead of like, you just figuring it out by yourself, if you need help.
> (SI, 5/2/2001)

As students became increasingly aware of the range of activities available to them with DM (test, tutorial workout, prescribed assignment, progress report review) they began to express their own preferences for learning with DM:

> Mrs. Hall: You have some new tests. There's two on integers and there's some on order of operations, part one and part two. There are some new things you can look at…
> GS: Instead of doing the tests, can I do the assignments if it's still the same?
> Mrs. Hall: Yes, if you still have assignments you don't have done. Ok. Lets go over and get started.
> (ON, 3/21/2001)

Chris candidly expressed his desire for measures of control over his own learning in math:

> I really like to have more control. Cause maybe like, somebody is stuck on one point here, but you want to keep moving. So like, over there, like maybe BR would be stuck on two plus two, but you want to go to four plus four [pause]. So we don't all have to wait for that one certain person.
> (FGI, 4/27/2001)

Chris felt that he was capable of determining an appropriate choice of activities and rate of learning for himself, using DM:

> Well, I like that you can go at your own pace, over there in the computer lab. You're not held back by other people and you can just go at your own pace. You can go with what you want to do, and what you think you're capable of learning.
>
> (SI, 5/2/2001)

Brian explained that DM enabled him to think about where he was going with math. It gave him a sense of direction and perspective with regard to his own learning:

Brian:	The computer lab is funner cause, you know [pause]. You want to know what's comin' up next and stuff.
Researcher:	How do you mean you want to know what's up next?
Brian:	You know, like the first one [tutorial math problem] will be talkin' about some buildings or somethin', and then he [Dijit]'ll be on some little scooter thingy all over the place. But you always know what you're doin' or where you're goin' with it.

(SI, 4/4/2001)

Tanya felt the choices DM afforded, enable her to target activities which would improve her understanding of math concepts:

> Like in math, it helps with tests and stuff, and you can actually understand it. You can pick, like what you want to do with fractions, and then go to the tutorial and stuff. It just helps with, like, your understanding. Like you can see how you're doing and, eh, it can get you back on track.
>
> (SI, 5/2/2001)

Tanya explained how important it was for her to be able to choose what she wanted to do, and feel good about her choices:

Tanya:	Here if you get done with your test, you can do what you want. Like you can get to one of their workouts or something like that.
Researcher:	Ok. And how do you feel about doing that?

Tanya:	Well instead of just, like, being told what to do, you get to think about what you're gonna do. Like you can choose what you wanna do.
Researcher:	Do you think you're making good choices?
Tanya:	Yeah. Ah-ha, like I know where I'm going.

(SI, 5/2/2001)

Brian suggested that choosing from the range of activities DM offers helped him to like math:

> Well, over there [in the computer lab] you can pick if you want to do a test, or if you don't, or you can have a bunch of time if you have to do make-up stuff. There's just more you can do to help you like it [math] better, instead of just doin' what the teacher tells ya. I liked to be able to pick what I wanted to do. It's better because over here [classroom] you have to do certain things, and over there you can pretty much do whatever, and you're still learning.
>
> (SI, 5/2/2001)

Given the choices DM afforded her, Beth told me that she too became more interested in math when learning with DM:

Researcher:	So, Beth, how do you feel about math, when you're learning with DM here in the lab?
Beth:	I like math here. I like coming to school on Wednesdays and Thursdays because we get to come here.
Researcher:	Really?
Beth:	Well, I'm more interested in it [math] over there [in the computer lab] than over here. Yeah. It's pretty good. I don't dislike it [math] as much as I used to [pause]. It's more fun and you get to do what you want. And there's more things to do over there.

(SI, 4/25/2001)

Beth told me that the real-world scenarios and the variety in DM helped her to understand the importance of math in the world:

Researcher:	So, now that you've been using DM to learn math, how important do you feel math is, in your life?

Beth:	It's more important.
Researcher:	Why would you say that?
Beth:	Because of everything ya did over there. Like if you want to grow up to build houses, you need to know math. Cause, like the housing development thing over there and all the other things, teach you how important math is.

(SI, 5/2/2001)

Given their initial bewilderment at having opportunities to make decisions about their own learning with DM, students quickly became familiar with the activity options offered by the DM system. Their experiences with DM became increasingly more positive, as they gained control over their own learning in the math class. Students' reflections on their experiences with DM suggest that they felt capable of making good choices about their math learning, they enjoyed making these choices, and they became more interested in learning math during the 10 week implementation process.

Student Interactions

Student-Teacher Interactions

For students, the social milieu for learning with DM was a powerful context for learning with this novel educational technology. In addition to the range of activity options afforded to students when learning math using DM in the Gateway lab, students were excited about the opportunity to talk with, and work with, one another while using DM. Mrs. Hall noted that students were much more likely to interact with those around them during their use of DM in the computer lab:

> I think there's more interaction over there. Like it's easier for them to just say to their neighbor, "What do you think about this?" or, "Could you help me with this?" or they're not shy about asking one of us either, you know, "I need some help over here" [laughs]. Now lots of times when they're working in the classroom they will just work and they won't ask questions. Because they can write something down, and you really don't

> know. I don't know why, maybe because it's so visible if we're walking around the room, as to what they're doing, that they'll say, "I need some help." But they might not over here [in the classroom].
>
> (TI, 3/28/2001)

Students discussed math much more frequently in the Gateway lab, when using DM, than in their regular math class. While Mrs. Hall was generally busy (preparing or reviewing DM tests) when students used DM in the Gateway lab, students were still much more likely to approach her with math questions when using DM, than in the regular math class. Student interactions with Mrs. Hall (while much less frequent than interactions with a peer) were generally in the form of questions, regarding:

1. Assigned tasks: identification and explication of teacher-assigned activities

> Beth: Mrs. Hall what are we doing this time?
> Mrs. Hall: Go to your assignment and continue with what you were working on last time.
> Beth: I think I'm done.
> Mrs. Hall: You can begin the new test, then. There are two of them there for you.
>
> (ON, 2/28/2001)

2. Tool affordances: use of software features to navigate and access activities within the system

> DS: Eh, how do I get done with this Mrs. Hall?
> Mrs. Hall: This is the place where you hit score test. [DS scores his test.] Now go to prescribed assignment [pause]. Menu. Now go to prescribed assignment. Now go to assignment. So you have three assignments there that you can work on.
> DS: Oh. So how do I get here again?
> Mrs. Hall: Well now that you've done it once, you can get here from the main menu, by clicking on prescribed assignment. But you have to generate it first, after you score your test [DS begins work on his first assignment].
>
> (ON, 2/21/2001)

3. Math concepts: assistance with a math problem

Integers: Part 1, Test, Question 12
Use the number line to determine which of the following statements is true about the absolute value of 4 and –4.
Select your answer.
-|4| = |-4|
-|4| not equal to |-4|
-|4| < |-4|
-|4| > |-4|

JR: Mrs. Hall, what's this number mean?
Mrs. Hall: This is always a positive number because it's talking about the
distance away from zero.
JR: So is this the same number?
Mrs. Hall: The same number, right. Except [pause]. Yeah. If the number's positive, it's the same number. Positive [pause]. Same number, but it's always a positive.

(ON, 4/5/2001)

Mrs. Hall told me that she received more questions concerning math problems (no. 3) when students used DM, than in the regular math class.

> I'm getting more questions from people who normally don't ask questions in class. Even questions, just like, "How do you do this?" or "Is this the same as this?" things like that, when we're working over in the computer lab. Maybe because if they have homework problems, like if they have thirty questions to get done, they want to get something down. They don't always care if it's right or not, because it has to be done, and they're going to get it done, whether it's right or not. They sometimes have that attitude: just get it done, get it done [in the regular math class].
>
> (TI, 3/28/2001)

Mrs. Hall suggested that her students would "probably agree that it [the DM math session]'s better than sitting in math class, because just of the different setting, I think" (CC, 4/19/2001).

Peer Interactions

Students agreed that the DM learning environment was very different from the regular classroom learning environment. Brian noted that the social dynamic in the computer lab with DM was significantly different for him: “Well the computer lab’s funner because, well, I don’t know if you’re supposed to or not, but you can talk to the person beside you” (CC, 4/5/2001). In support their regular math conversations, many students made exhaustive efforts to synchronize their tutorials and workouts with those seated nearby. The following description of JF GS and JM’s first DM tutorial humorously depicts their efforts to complete the DM screens in unison:

> Essentials of Fractions: Tutorial 2
>
> JM: I need to hear Josh’s [speakers]. [To JF] Can you turn yours up so we can hear?
> JF: I’ll press stop and let you guys catch up
> JM: Don’t press anything now. Just stop!
> GS: What’s going on here? This guy’s like [pause] talkin’ and...
> JF: [Interrupting] Just stop and wait!
> JM: Wait! Wait until I catch up with you!
> JF: Are you ready? We’re going to click go.
> GS: Ready, set, go!
> DM: But, lets take a closer look at how they actually drill for ground water, Dijit... [JF, JM and GS interrupt the DM tutorial with intermittent giggles.]
> GS: Ready, set, go!
> DM: So if each disc, represents one kilometer, then each part of the disc.... But hold on a minute there, buddy...
> GS: [Laughing] Let’s move it on there, buddy! Ready, set, go!
> DM: Now it’s your turn, click on the parts of the second disc that represent one half of one kilometer.
> GS, JF: Ready, set, go! [Each of the three student correctly selects the disc representing one-half and the trio begin the next screen together.]
>
> (ON, 2/21/2001)

When using DM in the computer lab, students had opportunities to assist each other in general ways; for example, to enter the system:

> CW: I forget my password!
> Mrs. Hall: You don't remember it?
> ME: [From the other side of the room] It's Leroy!
> Researcher: Wow. How do you know that?
> DS: Cause he said it when he logged in last week!
>
> (CC, 4/25/2001)

or to motivate one-another:

> GS: Holy tractor! Look at all the questions!
> JM: Aren't you going to try?
> GS: I guess.
>
> (ON, 3/6/2001)

Brian frequently worked with CW to understand and resolve math problems:

> Researcher: Do you think that you talked much about math in the lab, Brian, or were more likely to be talking about any old thing? You don't have to speak for the others, just yourself.
> Brian: Yeah. I got to talk to CW about it. It's better that we get to discuss it, to help each other find out the answers an' stuff. You can help somebody, or you can get help.
>
> (SI, 4/4/2001)

Chris noted that he also liked to be able to talk to BR or JF (who sat at either side of him) about math or to assist them if he could:

> I forget what it was about but they gave us the numbers but they didn't put the decimal point in, and in here, I put it wrong. And then the next day, BR put it wrong, so I was able to help him with that.
>
> (SI, 4/4/2001)

> Researcher: Did you spend much time talking about math or about other things in the computer lab, Chris?

Chris: Well, probably both. Because, I'm not going to lie and say that we weren't talking about other stuff, because of course, we were, because people actually do that. But, em, we did ask each other questions about a certain topic if we didn't understand, which was good fun. And I think it helped a lot, like with understanding it.

(SI, 5/2/2001)

Beth also indicated that she liked to be able to ask one of her peers for help, if needed, in the computer lab:

> I liked that like if you needed help with the problems you could ask, JC or AB or somebody [pause] like what they got, or what they put or what they got on that problem or how to do it or somethin'.
>
> (SI, 5/2/2001)

AH was unsure whether or not to tell me that she and Tanya frequently collaborated on solving math problems when using DM in the computer lab:

> AH hears me talk into my recorder. I'm logging student activities. She looks around.
>
> Researcher: I'm just describing what you're all doing. Are you girls working together?
> AH: No. Well, eh [pause] a little bit, like if I need help or she needs help.
>
> (CC, 3/6/2001)

Tanya and AH regularly discussed the application of appropriate math rules, procedures, or methods when working on DM math problems:

> Decimals: Part 2 (Test)
> Marcus ran the 100 meter sprint in 12.28 seconds. His time was 1.8 seconds short of the school record. Mike came in second place, 2.1 seconds behind Marcus. How far short of the school record was Mike? Express your answer as a decimal. Type in your answer.
>
> Tanya: [Seeing that AH is struggling with this question, Tanya asks her neighbor, AH] So what do we need to know here?

AH:	[Sounding uncertain and confused] How much short of the school record was Mike?
Tanya:	So you just got to find out the school record, and to do that, you got to take this minus this. Twelve point two eight, minus that.
AH:	That's what? I just did that.
Tanya:	What did you get? [Reading AH's result] Fifteen point o eight?
AH:	Ten point 48 now.
Tanya:	That's what I got. So that's the school record right there, ten point four eight. Write that down.
Tanya:	Right, now we've figured out the school record, and his was, em [pause]. Then you've got to take Mike's time, and he was slower than this guy, right? Because he came in second place. Ok, Yeah. So you add this one to this, if this was Marcus' time.
AH:	You add two point one plus 12 point 28.
Tanya:	Add it up, yeah. What did you get?
AH:	Ten point 18.
Tanya:	Huh?
AH:	Oh, I didn't add it up. Fourteen point three eight.
Tanya:	Then you would subtract his time from the school time.
AH:	So [pause] this minus that.
Tanya:	Yeah. Two point five.
AH:	Two point nine.
Tanya:	I got [pause]. What was the school [pause]. Fourteen point three eight, was that what you got?
AH:	Point three eight, minus 10 point 48 [pause]. Three point nine.
Tanya:	[The five minute bell rings.] Jeez! Thanks, AH! [Tanya corrects her mistake, and both she and AH move on to the next question.]

(ON, 3/6/2001)

While using DM, students frequently argued with one-another about math. Their discussions often began with a request for peer help, or an evaluation of optional answers for a given math problem. Students challenged one-another to justify and defend explanations or examples provided. Table 10 describes different activities that students engaged in during these math conversations, discussions, and arguments. Students generally progressed through a number of the activities described in Table 11, while working on math problems with their peers.

Table 11

Components of Students' Discussions about Math, while Using DM[a]

Activity	Examples
Request help	"Which one do I click on, here?" (seek advice)
	"Oh man! What's this about, anyway? (seek help interpreting)
	"What's an absolute value, again?" (seek definition)
Provide assistance or advice	"Click that one, man!" (provide answer without justification)
	"Because that's relationship." (provide partial explanation)
	"Because it's the difference from Jack's home to the school. Do you see that there?" (provide explanation, support)
	"Because it's five over two." (provide example of math concept)
Evaluate or compare options	"That looks wrong." (assess)
	"This one is better." (compare)
	"Yeah, I had that one figured out, too." (compare, contrast)
Seek clarification	"How do you know it's that one?" (seek justification)
	"You did what, again?" (seek reiteration of suggestion)
	"So why did you do that, there?" (seek justification)
Accept option	"That's true." (agree)
	"Cool!" (accept without indicating motive)
	"Yeah! That's what I was thinkin' – divide and then simplify. I got that too!" (accept as confirmation)

Reject option	"No it's not! That's a proper fraction there, JM!" (contradict)
	"No. Eight's the denominator here." (explain)
	"See, smartie! I told you it was this one!" (self-applaud)
Defend choice	"Oh, no it aint! That's the opposite of an improper fraction, there, GS!" (reject, justify)
	"It has to be this one – I know those are all wrong!" (justify by elimination)
	"If you add them up you'll get four sixths, and that has to be two thirds in lowest terms." (recall mathematical proof)

Note. [a]Excerpted text from CC's recorded in the Gateway computer lab

Exploring students' conversations while using DM, informs our understanding of their experience with the DM educational technology. Table 12 depicts KM and JR's progression through a number of the stages described in Table 11. Both KM and JR engaged in a series of speech acts where they each proposed their own solution to the question (offered assistance), justified this suggestion (defended perspective), asked why their peer would not accept this answer (sought clarification) and, ultimately rejected the alternative answer being proposed (rejected assistance). The two students did not compromise on the final answer to this math problem:

Table 12

Coded Transcript of Students' Math Discussion: Unresolved[a]

Decimals: Part 5, Question 17

[What is 0.4 x 0.8?

Express your answer as a fraction in lowest terms. Type in your answers.]

Speaker	Transcribed CC	Activity
Researcher:	What are you guys chatting about?	
KM:	We're arguing about the answer.	
Researcher:	So what do you think the answer should be?	
KM:	Eight twenty-fifths.	Offer assistance
JR:	Did you read the question?	Seek clarification
KM:	Yeah, I did. It says express your answer as a fraction in lowest terms. See, I did that, JR!	Defend choice method/answer
JR:	You can get it lower. See that would be thirty-two over a hundred. And divided into thirty two and a hundred equals that. So thirty-two divided by four would be eight, and divided by a hundred would be twenty-four.	Reject answer, offer assistance, defend perspective
KM:	You can't switch them into fractions before you multiply.	Reject assistance
JR:	Why not?	Seek clarification
KM:	What did you get? [pause] One over two! It doesn't simplify like that. I'm right, JR!	Evaluate options, reject answer, defend perspective

Note. [a]CC, 3/28/2001

JF, and GS engaged in a similar exchange while answering a problem in their DM fractions test. The coded transcript of their discussion or conversation is described in Table 13:

Table 13

Coded Transcript of Students' Math Discussion: Resolved [a]

Fractions: Essentials of Fractions, Question 8

How many fourths are in 8/8? Type in your answer.

Speaker	Transcribed CC	Activity
GS	Let's see [pause]. Eh, four.	
JF	There's two, not four!	Evaluate options, offer assistance
GS:	Oh man!	(Seek assistance)
JF:	Four goes into eight twice, not four times.	Offer assistance/ explanation
GS:	Four. Two fourths is a half, man!	Seek clarification
JF:	And that's eight eights. That's a whole.	Evaluate/compare, defend choice
GS:	Eight eights is the same as four fours. See I told you, JF!	Evaluate, compare/ defend choice
KM:	I told you!	Defend choice

Note. [a]CC, 2/21/2001

Mrs. Hall's students frequently expressed their preference for working and learning in pairs or groups. Some students explained that learning with others was simply more fun than learning alone. Students felt that their use of DM was enhanced by the opportunities they had to talk with one another:

Chris:	I agree with everyone, but if, like say, in the future, we all turned over to technology, and we're sitting in front of computers, em, you wouldn't have the option of asking the people, like if you don't understand something, and we might have to figure out different ways to talk, like with the computer.
Researcher:	Chris raises an interesting point, and it's something I'd like to ask you. How do you feel about your opportunities to talk in the math lab?
Chris:	I know several times when I was sitting there, I was talking to JF, we were talking about how to help each other out on the questions in the test. It's really, like sitting next to people and you're both, like working on different things, or the same thing, and it's good to talk about it.
Researcher:	BR, you mentioned on your e-mail to me that you preferred to use the RVDP stuff in school than at home, could you talk about that?
BR:	Yeah. It's a different environment thing. You know, you're just sitting around doing things, and you find out something new and neat that you just got to show some one, you know, like the people around you. Or if you're getting frustrated with something, the other people are there to like, talk to you about it.
BS:	It makes it more enjoyable to have, like friends around, you know, when you're doing that stuff.

(FGI, 4/27/2001)

Math Motivation

Given the opportunity to choose math activities, and how to complete them (alone or with a peer), Mrs. Hall's students experienced increased interest in math, during their ten-week use of DM. Students consistently expressed their enthusiasm for learning math with DM in the computer lab:

> JC is the first to arrive to the classroom. I am checking returned consent forms at the back of the room.

JF: Are we going to the computer lab today, Miss FitzPatrick?
Researcher: Yip.
JF: Excellent. [Mrs. Hall returns and stands in the classroom doorway. Addressing her, JF asks] Mrs. Hall, we're going to the computer lab today?
Mrs. Hall: [Confirming] Ah-ha.
JF: Cool!
Mrs. Hall: [AH is the next student to arrive to class. She begins to move the stack of novels on her table to another student desk. Mrs. Hall addresses her] AH, don't move those, we're going to the lab.
AH: Cool! Did we go there yesterday? [AH was absent.]
Mrs. Hall: Ah-ha.
AH: [AH mutters her disappointment and asks Tanya] So what did I miss, yesterday?

(CC, 3/1/2001)

DF: Are we going to the computer lab, Miss FitzPatrick?
Researcher: We are.
DF: Oh good.
MG: [MG arrives and reiterates] Are we going to the computer lab today?
Researcher: Ah-ha. [MG raises his hands in the air, as if in triumph. I ask] Is that good news?
MG: Oh yes it is!

(CC, 4/4/2001)

One student announced, "I *always* have fun in the computer lab! I wish we could come here every day" (CC, 3/6/2001). When asked what he liked most about doing math in school, Chris responded, "Well, the likes would probably have to be on Wednesday and Thursday because we get to come in here [the computer lab] because it's more fun, than sitting over there [in the classroom]" (CC, 18/4/2001).

When asked how she felt about learning math using DM, one student exclaimed, "Oh, the computer stuff definitely helps it!" (3/21/2001). Her peer explained, "Just the fact that it's, like on the computer, it kinda makes the math a lot more fun, because the classroom is so boring" (3/21/2001). For another, "It [the math]'s just better because

…you know, you're on the computer, and just the word, *computer*, makes it better, for some reason" (4/27/2001). Chris explained that the technology itself provides a motivational context for math learning.

> It's, em, I guess more people use technology now-a-days, I guess, so I'd probably want to use a computer more than just sit at a desk and do homework, or do practice problems or work on the next set. So I think that people would rather use a computer to learn than just sit at a desk.
> (FGI, 5/2/2001)

During our first visits to the computer lab to use DM, I noted that Mrs. Hall's students were busy with math when using DM; they accessed the system with little delay, engaged in math-talk with one another, completed their assignments, and frequently remained in the computer lab beyond the five-minute bell which signals the end of math work, in the regular math class. To further explore my initial impression that students spent much of their time on-task in the computer lab with DM, I begin to routinely describe the activities of (a random sample of) approximately one third of the students (five from the fourth period class, and six from the eighth period class), beginning on February 21st, and continuing until April 25th. I described the activities of each random sample of students, approximately ten minutes into each class session with DM, occasionally repeating the activity with a new sample of students ten minutes before the end of each session. Table 14 summarizes activities demonstrated by students while using DM in the computer lab, classified according to *time-on-task* and *time-off-task*. To evaluate time-on-task for students working independently and silently, I focused on student advancement through the DM activity system. Students who progressed from one screen to another while demonstrating interaction with the math presented (reading, computing) were classified as on-task. Students who did not progress from one screen to another, or who clicked the DM buttons without obvious direction, were classified as off-task. All student interactions with hardware (monitor settings, restart button) were automatically classified as off-task given the high performance of the hardware since its purchase less than one year previously.

Table 14

Description of Time-on-Task Categories

Time-on-Task	**Time-off-Task**
Student engaged in math talk:	Student talk is not about math:
Student discusses math with peer or teacher	Student asks peer for gum or candy
Student reads or thinks-aloud math	
Student engaged in math activity:	Student activity is not about math:
Student performs calculations using calculator or paper	Student reads book of English poetry
Student proceeds from one screen to another without visible distraction	
	Student is disengaged from math activity:
	Student randomly clicks buttons on screen without obvious purpose or progression
	Student closes DM program and logs off computer before the 5 minute bell
	Student faults hardware for time-off-task:
	Student restarts computer
	Student changes monitor settings
	Student handles power chords

The student activities represented in Table 14 were based on 21 recorded observations of student activity (for each student sample) taken in 15 DM classes. To explore students' claims of high levels of engagement with math in the DM class, I used the categories represented in Table 14 to classify the behavior of each student within each sample as either on-task or off-task. The raw data for this time-on-task analysis is presented in Appendix R. Figure 6 presents a graphical representation of this time-on-task data, which was taken during the months of February, March and April in Mrs. Hall's DM classes.

In contrast with the descriptions of students' time-on-task in the regular math class (chap. 4, p. 100), Figure 6 shows that an average of 95% of students were found to be on-task with math, during Mrs. Hall's DM lessons. A maximum of 100% of students in the DM lesson were frequently observed as *on-task*, while the maximum percentage of students *off-task* was documented at 18%. From the first until the final log, there is very little variation in students' time spent *on-task*, while using DM. Students' engagement with math in the DM class, defined operationally here as time-on-task, began and remained high throughout these three months. This analysis supports students' claims that they used the opportunities afforded by DM to talk about and do math activities during their DM math classes with Mrs. Hall.

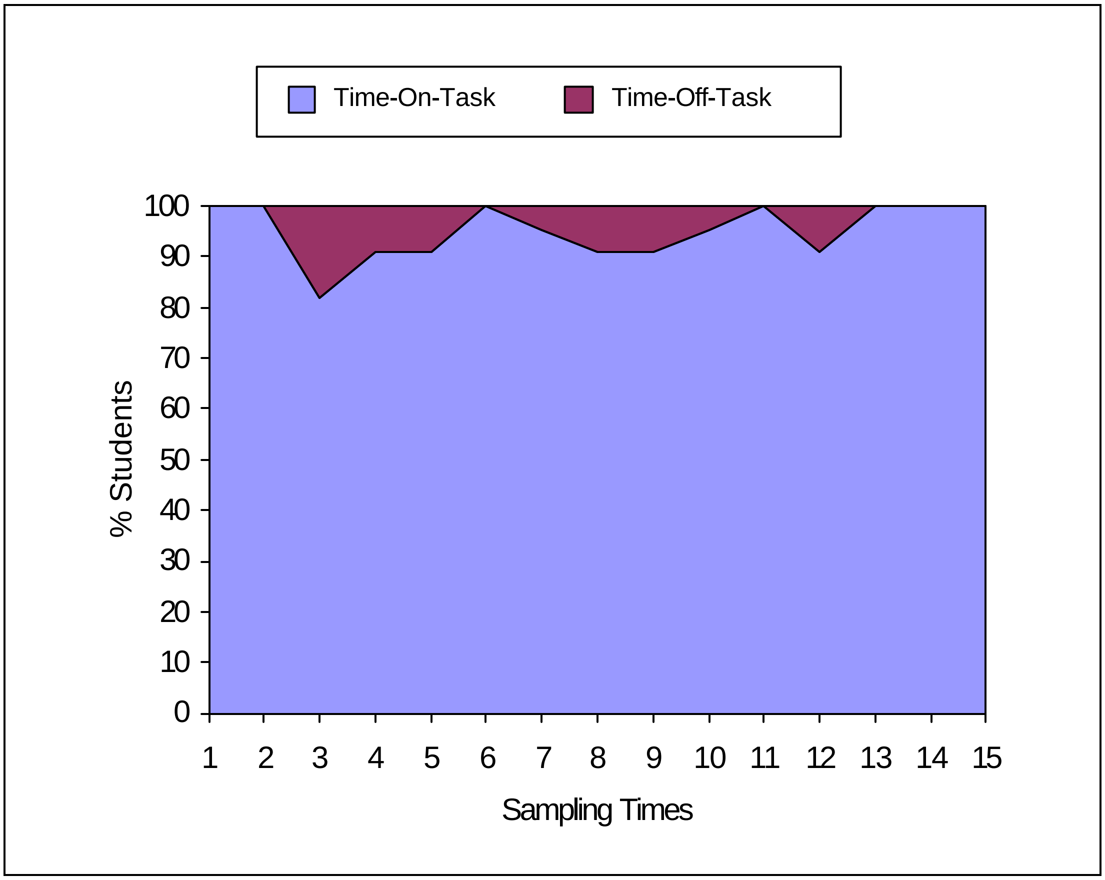


Figure 6. Students' Time-on-Task with DM

Tanya explained that using the computer to learn math with DM was more fun than learning math in the regular classroom, where it was difficult to concentrate. She suggested that the variety and choice in DM motivated her interest in working on math:

> Over there the choices are more fun and there's more of them than over here. You've just got to sit here and do what she [the teacher] says. Like the workbook pages [pause] are just black and white [pause]. It's hard to concentrate. And over there it's colorful [pause] and it's more fun. And you just have so many more choices.
>
> (SI, 4/4//2001)

Beth also compared the choice of activities DM offered her, with the structured monotony of the regular math lesson. She explained that with DM there was an ample resource of activities. She felt the DM environment in the computer lab was definitely a motivational and productive one for engaging in math activities:

> Well, it's like more fun, to come over here and get on the computers, and like, have the thing talk to ya [laughs]. You get to do fun things over here, instead of just, like [pause] being over there [in the classroom], and just like bein' told the same things to do, and what set to do and to just do it. And then, when you get done, you like don't have anything to do. Over here, you always have stuff to do, on here. Because they like put tests on with everything else. Over there [computer lab] the choices are more fun and there's just more of them than over here [classroom].
>
> (SI, 4/5/2001)

Beth suggested that learning math using DM actually made her feel better about the math itself, and more productive in general:

> Cause you actually want to do it, then. And it means you actually want to work harder and, like, get it done, and see how much you can cover and stuff. For me when it's more fun, then I like to do it.
>
> (SI, 4/5/2001)

Brian contrasted his poor work ethic in the regular math class, with his sense of efficacy when learning with DM:

> Well, here I could actually get my work done. I could actually do my work in here. Over there I would do nothin', cause I'm lazy and it's boring. Here it's easier and funner to be clicking numbers on the computer screen. It's a lot better over there than it is over there. It helps [pause]. It gets you to like it a little more, so you actually get to do stuff. You want to do work. You don't just sit there.
>
> (SI, 5/2/2001)

Chris suggested that with DM "you're there and it's there, and there's just so much you can do [pause]. The time, eh, just passes so quickly when I'm using it [DM] in the computer lab."

PART III: INTERLUDE: IMPLEMENTATION OUTCOME

Mrs. Hall's Implementation Experiences

- At the outset, Mrs. Hall hoped that her use of DM would *refresh and renew* her eighth grade math classes. She hoped DM would support students' understanding of math concepts, and increase their interest in math and their awareness of the relevance of math.
- In retrospect, Mrs. Hall said she had *lacked confidence* regarding her implementing DM. She had known little about the RVDP system or how best to use it: "I didn't feel very confident at first, just because it's new, and of course until you use something, you don't really exactly know what you're doing until you actually have to use it yourself" (5/2/2001).
- Mrs. Hall thought that the *limited professional development* support she received, combined with the time-lag until her use of DM with students, were impediments to her effective implementation of the new math resources:

> Even with the in-service we had with Eileen [Riverdeep Implementation Specialist], it was short, just a few hours in one evening. And so [pause]. But that kind of happens, you know, sometimes you get in serviced, and then there's a big lull in time until you have to use it. And then you don't really remember what you did learn, you know to try to apply it. If you don't use it right away.
>
> (TI, 5/2/2001)

- Mrs. Hall explained that she had *insufficient time* to explore the supporting lesson materials for the RVDP math resources prior to or during the implementation process:

> Well, see, I didn't have that much time to look at the lesson plans that were available, the handouts that were available, that you might want to [pause] in your classroom, use those kinds of things, to either extend a lesson there or maybe even introduce a lesson in that way here before you would go use it. So I would like to have had the time to get into that

aspect of it.

(TI, 5/2/2001)

- Mrs. Hall implemented DM in ways that *replicated her traditional instructional methods* for teaching math. She used DM to reinforce math concepts previously learned by students with the regular math text from the Saxon scheme, and to test students' knowledge of math concepts:

> I guess, what we've been using it for is basically reinforcement [pause]. I looked at what I was already doing. And really on that portion of it, the choices are fractions, decimals and percents. I just thought well, they've had some background in each of those things, so I chose those.
>
> (TI, 4/22/2001)

- The transition from the regular math lesson (using the Saxon scheme), to the DM math lesson, was not an easy one for Mrs. Hall. It was characterized by *change*. Mrs. Hall explained, "It's hard to incorporate it right here whenever you have to like, even change locations to go there [to the computer lab]" (TI, 5/2/2001).
- Mrs. Hall described the *pressure* she felt throughout the implementation process to cover the district-mandated Saxon curriculum, and to keep progressing in that direction:

> [With DM] I want to say, let's move along to the next activity [pause]. So I get a little nervous, I guess if they're spending too much time in one thing, because, I guess that's always what we're used to [pause] keep moving, keep moving, keep moving, with the material. So I guess that's what comes from teaching all these years, you need to keep moving and we always feel like we have to cover material to get the learning.
>
> (TI, 5/2/2001)

- Mrs. Hall suggested that in the future, she might continue to use DM one day per week as a *supplement* to the existing Saxon Curriculum:

> Well, actually I think I would probably continue using it, maybe if the lab were available for just once a week [pause]. I just have to, I guess, eh [pause] re-think how we feel about how far you have to get in the book,

you know.

(TI, 3/28/2001)

- When asked how she might feel about continuing to use DM with her students more frequently, Mrs. Hall explained that this decision would necessitate a *restructuring of thinking about curriculum*, one which must take place in the minds of those beyond the walls of her classroom:

> That would concern me, unless we could devise a study group of students, where no one's going to be concerned how much material we covered because since we are addressing standards, and that does that, supposedly that would be ok. I think as well as teachers having a different attitude about it, probably school administrators and school boards would take a different perspective on things, I think from like top to bottom, the whole way down too.
>
> (TI, 5/2/2001)

Students' Implementation Experiences

- Mrs. Hall's eighth grade students initially expressed their *enthusiasm for using technology* to support or replace traditional school-work. Chris explained, "I'd probably want to use a computer more than just sit at a desk and do homework, or do practice problems or work on the next set" (FGI, 5/2/2001). Students were excited about their use of DM to learn math. Another student explained, "It [the math]'s just better because [pause] you know, you're on the computer, and just the word, computer, makes it better, for some reason" (4/27/2001).
- Students expressed *negative attitudes toward math* in general, and the regular math class using the Saxon curriculum.
- During their initial use of DM, students responded with *frustration* to Mrs. Hall's lengthy teacher-assigned tests. In a culminating focus group session one student

proclaimed, “The tests were too long.” Another added that “some of them were really long. Like one was 66 questions” (FGI, 4/27/2001).

- When students became familiar with the features of the DM menu options and could use them purposefully to access DM activities, they began to contrast the *many choices* available to them in the DM math environment with the limited choices in the regular math classroom. Beth explained:

> If you wanted to do a test that day, or if you had a prescribed assignment, like it would just give it to ya [pause]. It [DM] shows you, like it tells you stuff about it [math], and then it gives you a problem, and if you aint got it right, you can either try it again or you can click a little button and it will show ya how to do it an’ stuff. You get to do stuff on your own. It explains it for you instead of like, you just figuring it out by yourself, if you need help [pause]. It’s cool.
>
> (FGI, 5/2/2001)

- The math class in the Gateway lab, afforded opportunities for students to *interact with their peers* while using DM. Brian explained that compared with the regular math lesson “the computer lab’s funner because, well, I don’t know if you’re supposed to or not, but you can talk to the person beside you” (CC, 4/5/2001). While using DM, many students spontaneously collaborated on math activities (synchronizing DM activities), and engaged in math talk (discussing, and arguing about, solution paths to math problems).
- Students described the *motivational effects* of using DM to learn math. They explained that math was more interesting to them with DM than in the regular math classroom. Students’ feelings of self-efficacy and success with math when using DM, translated into improved attitudes toward school on the days that they used DM in the

Gateway lab. Frequent logs of students' time-on-task support their self-reports of high levels of engagement with math while using DM.

- In culminating focus group and individual student interviews, students unanimously expressed their *preference for continuing to use DM* in their math class.

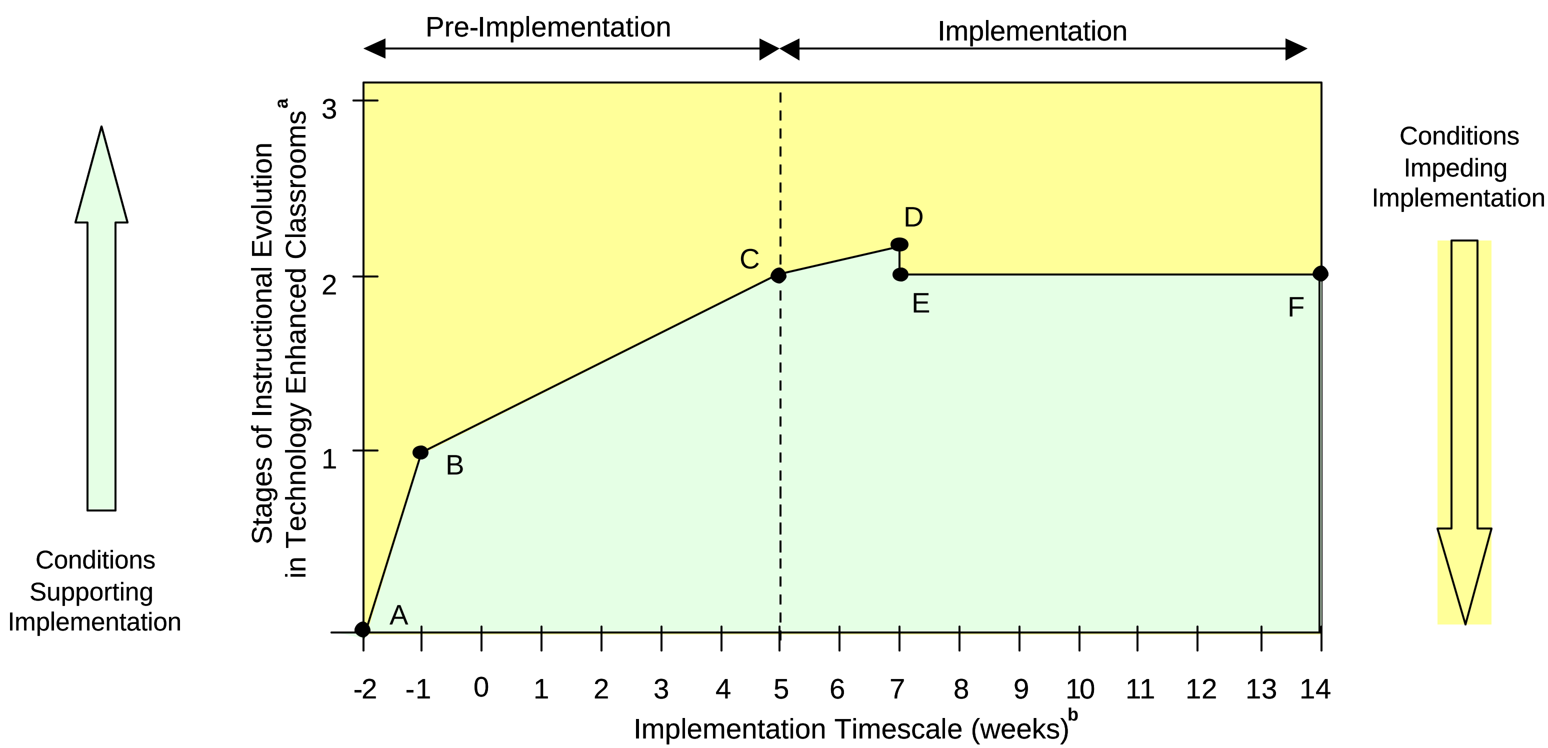
CHAPTER 5

DISCUSSION OF FINDINGS

This research explored the experiences of one teacher and her 32 students during the semester-long implementation of an educational technology -understood as an instance of curriculum change, in their eighth grade math class. The point of departure for this study was the transition from the regular math class to the computer lab and the use of the interactive learning system therein. Schwab's four contexts provided the framework for exploring the actions of the teacher and her students within the research setting. This chapter discusses the research findings beginning with the teacher's experience of the interactive learning system. Conditions that facilitated and impeded the teacher's decision to adopt the educational technology innovation are discussed. Using Sandholz et al's (1997) model of teacher's instructional change in technology enhanced learning environments, changes in the teacher's instructional model are explored and discussion focuses on my interpretation of the lack of any significant teacher change (small effect size: teacher as unit of analysis). I provide four interrelated reasons for this lack of teacher instructional change. Primary implementation experiences for students focus on learner-control vis-à-vis the tools of the system, opportunities for spontaneous peer interactions, and increased motivation in the DM math class (larger observed effect: variable unit of analysis). The chapter concludes with recommendations for future research and for the implementation of educational technologies in classrooms.

<u>Teacher's Experiences with DM</u>

Figure 7 presents a diagrammatic representation of Mrs. Hall's implementation of the RVDP innovation. Mrs. Hall's ten-week implementation is represented according to Sandholz et al.'s (1997) stages of instructional evolution in the ways teachers implement educational technologies with their classes, derived from their ten-year research with teachers in the ACOT project. Three of these five instructional stages (Sandholz et al.) are represented in Figure 7. These instructional stages provide a framework for my initial exploration of Mrs. Hall's implementation of DM, with the caveat that this research presents a snapshot of one teacher's fourteen-week experience. Following discussion of Mrs. Hall's implementation of DM, I suggest that the highest level of evolution in instructional practice demonstrated by Mrs. Hall represents a point of *Implementation Impasse*. I provide four reasons for this implementation impasse and explore each in turn.



Note. [a](Sandholz et al., 1997) [b]This Research was conducted during weeks 1-14

Figure 7. Diagrammatic Representation of Mrs. Hall's Implementation of DM

Pre-Implementation

Entry

When the Westridge School District administration decided to increase the Junior-Senior High School's investment in educational technologies, i.e., hardware (22 computers in the Gateway lab, individual workstations in teacher's classrooms), and software (232 RVDP licenses for eighth grade students and students with IEPs), an instructional technology already existed in Mrs. Hall's eighth grade math class (Point A). This text-based technology was standards-aligned and teacher-driven. Mrs. Hall used the district-mandated Saxon math scheme to teach each of her daily math classes. The common tools used in Mrs. Hall's math lesson were the textbook, blackboard and worksheet. These tools were used in combination to support teacher-lecture and student seatwork during Mrs. Hall's eighth grade math classes. The ACOT researchers suggested that during this first pre-implementation phase, with the arrival of educational technologies in schools "real school… was firmly in place" (Sandholz et al., 1997, p. 37). The researchers referred to this stage of school adoption of educational technologies as Entry (Point B).

From this stage of entry (the advent of educational technologies in classrooms with pre-existing instructional technologies), Mrs. Hall decided to use the RVDP interactive learning resources twice weekly with each of her two lower level eighth grade math classes (Point C). Conditions surrounding Mrs. Hall's decision to implement the RVDP innovation are explored in the context of her routine use of the district-mandated Saxon math scheme to teach math, and the recent procurement of educational technologies for by the Westridge School District administration.

Conditions Supporting Adoption

Table 15 presents a framework for exploring Mrs. Hall's decision to implement the RVDP interactive learning system. Using Ely's conditions for implementing educational technologies (1976, 1990, 1999), teacher, local, and external factors are described as supporting, or not-supporting (impeding) Mrs. Hall's decision to adopt the RVDP innovation.

Table 15

Conditions which Supported and Impeded Mrs. Hall's Adoption of the RVDP Innovation[a]

Supporting Conditions	**Impeding Conditions**
Dissatisfaction with status quo	Lack of knowledge and skills
Availability of resources	Lack of time
Commitment	Lack of Participation
	Leadership

Note. A further condition described by Ely, *Existence of Rewards or Incentives*, is not represented in this analysis. It was not discussed by Mrs. Hall during this study, and therefore cannot be interpreted as significantly supporting or impeding her implementation.

[a]Ely (1999)

Dissatisfaction with the Status Quo

As the first teacher at the Westridge Junior–Senior High School to adopt the RVDP resources, following Cuban's (1998a) analysis, Mrs. Hall could be described as a classic *early adopter* of an educational innovation. Cuban explained, "Even if you wanted to do the crude way of dividing the teachers into parts, there's a certain percentage who are going to be early adopters of any innovation that comes along because they want to renew themselves" (p. 38). Prior to her implementation of DM, Mrs. Hall frequently expressed her desire for renewal and rejuvenation in her math teaching at Westridge. In his five-year study of how teachers change and develop throughout their lives, Huberman (1993) also noted that teachers who desired educational innovation and reform (40% of those interviewed) expressed a strong need "to renew themselves… with new pedagogical experiments" (p. 164).

The RVDP learning system represented a novel pedagogical experiment for Mrs. Hall who frequently spoke about the monotony of the tightly structured Saxon math scheme, and the lack of opportunity to deviate from, or supplement, the text. Mrs. Hall also hoped that the RVDP innovation would renew her students, whom she claimed lacked motivation for learning in the regular math class. Mrs. Hall's dissatisfaction with the *status quo* (regular math class using Saxon) is evident in this desire for both self-renewal and student-renewal. From the outset, Mrs. Hall's hopes and expectations for DM were expressed as outcomes or effects of the implementation. Mrs. Hall was unsure how this process might begin to take shape in her eighth grade math classes. From the outset, the success of Mrs. Hall's proposed implementation effort was plausible: Would her dissatisfaction with the status quo, and her focus on the innovation outcome be sufficient to see her through the complexity of this curriculum change process?

Access to Resources

Mrs. Hall's increased access to novel pedagogical tools also motivated her decision to adopt the RVDP interactive learning system. A suite of educational technologies had recently been procured by the Westridge Junior–Senior High School and made available to Mrs. Hall -most notably her classroom computer, the Gateway lab and the RVDP interactive learning resources (complete set of RVDP software CDs, DM user manual, packet of student DM materials, lesson plans, correlations and additional RVDP resources available on-line). Mrs. Hall also received assistance in using the DM teacher management system from Mr. Mercer, the recently appointed technology coordinator for the school district.

Local Commitment

The school district's commitment to Mrs. Hall's frequent and prolonged access to the RVDP interactive learning resources was evident in their recent purchase of 232 licenses for the use of RVDP resources by eighth grade students, over a five year period (Entry). While the decision to implement during the spring semester was optional, all eighth grade math teachers would have to use the RVDP resources with their students beginning in the Fall 2002 semester.

Conditions Impeding Adoption

Low Knowledge of Innovation

From the outset, Mrs. Hall was concerned about her limited knowledge of the RVDP resources. Table 16 outlines Mrs. Hall's levels of *awareness*, *principles*, and *how-to* knowledge (chap. 2, p. 29-30) of the RVDP resources prior to the implementation:

Table 16

Mrs. Hall's Knowledge of the RVDP Innovation

Rogers[a]	Mrs. Hall
Awareness knowledge	High
Principles knowledge	Low
How-to knowledge	Low

Note. [a](Rogers, 1995)

Mrs. Hall's fifteen-year-use of the Saxon scheme at Westridge had resulted in a proficient, practical pedagogy for math teaching. Mrs. Hall's primary instructional technology (Saxon math text) had not changed during this time, nor had it been supplemented by educational technology innovations. In her twenty-four year teaching career, Mrs. Hall had not previously implemented educational technologies with an entire class, for a full class period. She explained that she herself was quite unfamiliar with the use of computers, other than for personal e-mail correspondence at home or at school. Given the recent and significant investment in RVDP resources by the Westridge School District, Mrs. Hall was aware of the high profile of the RVDP innovation among the school administration (high awareness knowledge). Mrs. Morrison, the RVDP specialist, had also showcased sample RVDP lessons during her three- hour in-service workshop with Mrs. Hall and Mrs. Lankheit. Following this brief in-service, Mrs. Hall expressed her interest in the system, but felt ill-prepared to use it with her own classes; she noted her anxiety concerning both *what* she should teach, and *how* she should teach using the RVDP resources (low how-to knowledge). With Mr. Mercer's assistance, Mrs. Hall gained in principles knowledge of the teacher management system for DM, but claimed she did not have time to explore the DM student learning system. Entering the implementation phase, Mrs. Hall was uncertain how the student and teacher management DM systems functioned for users (low principles knowledge). She was expected to teach with an innovation she herself had not learned to use. How would Mrs. Hall's partial knowledge of the RVDP system affect her implementation with students?

Lack of Time

Mrs. Hall suggested that even her one brief professional development session with Mrs. Morrison would have been more beneficial, had it occurred closer to her own implementation of DM. Mrs. Hall received this in-service training six-weeks prior to her use of DM with students. During this six week time period, Mrs. Hall also received on-site assistance from Mr. Mercer in gaining access to the teacher management system for DM. Given her own busy teaching schedule (chap. 4, p. 87), Mrs. Hall had little opportunity to explore the RVDP resources during the course of the school day. She frequently discussed *time* as a mitigating factor in her preparations to implement DM with her students.

Lack of Participation

The RVDP interactive learning system was introduced to Mrs. Hall as a district-mandated initiative to target improved math skills for eighth grade students. Mrs. Hall had not been involved in identifying and selecting the most appropriate educational technologies for her math teaching. Her participation was required following the critical decision (made by the school administration) regarding the most appropriate educational technology resources to improve eighth grade math skills. One would assume that Mrs. Hall's expertise -her familiarity with the content of the current math program (Saxon), and her own personal pedagogical preferences should have informed the selection of math resources to be used by her, for five consecutive years.

Mrs. Hall's early involvement in the identification and selection of novel math tools to be used by her would surely have increased her knowledge of the innovation, and her interest or investment in successfully implementing it. Understanding a teacher's implementation of an educational innovation is often "a question of whether innovations have been imposed on the teachers or whether they arise from the collective experiences of their work" (Huberman, 1993, p.165). The lack of obvious concern for Mrs. Hall's expertise in identifying the most appropriate innovation for use in her eighth grade math classes, suggests a limiting characterization of her professional role as teacher, and a lack of awareness of the complexity of *mandated* change.

Lack of Leadership

As a pioneering early adopter of the RVDP resources, Mrs. Hall did not receive the support of a network of (RVDP implementing) colleagues during this implementation process. Given the recent adoption of the RVDP innovation within the school, leadership support regarding use of the system was not available to Mrs. Hall.

For these four reasons cited: lack of knowledge of the innovation, lack of time, lack of participation and lack of leadership, Mrs. Hall explained that she felt somewhat ill-prepared to implement the RVDP resources. How could Mrs. Hall be expected to implement an instructional innovation which she had not chosen, knew little about, had little time to explore, and with which her colleagues were unfamiliar? Mrs. Hall's feelings of lack of preparation for implementing educational technologies are mirrored in a recent report by the National Center for Education Statistics (NCES). NCES researchers found that only 33% of teachers surveyed reported feeling well or very well prepared to use computers or the Internet in their schools. Sixty-six percent of teachers sampled stated they felt only somewhat prepared (53%) or not at all prepared (13%) to use these educational technologies (Rowand, 2000). Sandholz et al. (1997) suggested that the challenges in implementing educational technologies might also be greater for certain teachers:

> especially those who are older and were educated *B.C.* –before computers –technology seems a foreign element, far from necessary to them in their teaching. They grew up without computers, were educated without them, and have taught their entire careers without them. (p. 39)

Implementation

Adoption

Mrs. Hall chose to implement the RVDP system with her two lower level eighth grade math classes in week five of this research. Although Mrs. Hall occasionally expressed her interest in exploring the full range of math resources provided by RVDP, she had not reviewed the complete set of activities offered by the system prior to her implementation. Mrs. Hall chose to implement the most highly-structured math component of the RVDP system, DM, with had been presented to Mrs. Hall and Mrs. Lankheit during their three hour in-service with the RVDP implementation specialist in early January. Given her lack of familiarity with DM, Mrs. Hall's initial use of the system replicated her typical pattern of instruction in the regular math class. Mrs. Hall did not use DM to teach new math concepts to students, but rather to reinforce math concepts previously taught to students using the Saxon math scheme. Mrs. Hall used DM tests to assess students' math skills, and to generate prescribed assignments that would regulate students' math work with DM, and curtail their opportunities for exploration of the system (Point C). Mrs. Hall used DM to regulate both the content (what) and the instructional methods (how) of students' use of the DM interactive learning system for math. By using DM to test and revise math concepts previously learned by students in the regular math class, Mrs. Hall was implementing DM in ways that would not compromise the regular Saxon math curriculum.

Mrs. Hall did not receive professional development support for her use of DM during the implementation process. She remained unfamiliar with a number of features of the DM system: the graphing tool, the glossary of math concepts, the local navigation panel, the bookmark tool, etc., and therefore did not guide or instruct her students on how to use them. Given her lack of experience with the other components of the system, Mrs. Hall was reluctant to explore the open-ended tool-based program, TM, and the supplementary on-line RVDP resources, with her students. Mrs. Hall's initial interest in using these interactive learning tools with her students did not sustain her exploration and use of these features of the RVDP math system during the semester-long implementation process. Mrs. Hall's lack of initiative in independently exploring the RVDP system, added to her frequently expressed desire for additional time to gain knowledge of the system, suggests that the technical support and instructional materials she received were insufficient to motivate her independent implementation of the RVDP innovation, over time.

Sandholz et al. (1997) noted that teachers in the initial stage in the instructional change process used educational technologies "to support text-based drill-and-practice instruction" (p.39). The ACOT researchers explained that given their lack of experience with the educational technology, teachers attempted to blend its use into the most familiar form of classroom practice -direct instruction. At the outset, Mrs. Hall was unsure how to implement the DM system with students (low how-to-knowledge). Three optional methods for implementing DM with students were described in her RVDP User Manual (2000, p. 6-7):

i. Presentation mode (teacher-led individual student presentation)

ii. Individual Instruction (self-paced learning for enrichment or remediation)

iii. Group Work (collaborative problem solving, student-led presentations)

Just as Mrs. Hall assigned her students to independent study-top desks in her own classroom, she consistently assigned one computer to each student for the duration of her ten-week implementation of DM in the Gateway lab.

Adaptation

In week 7 of this research, Mrs. Hall spoke about her students' increased engagement in math talk with their peers and with herself, in the Gateway lab. Mrs. Hall suggested that students were much more likely to ask her math questions while using DM than in the regular math class (Point D). Sandholz et al. (1997) suggested that the next stage in their teachers' instructional change process, Adaptation, was marked by an acknowledgement by teachers that their "students were increasingly more curious and assertive learners in the technology-rich classrooms" (p. 42). Despite her perception of some changes in students' learning practices, Mrs. Hall did not initiate change in her typical interaction with students. Mrs. Hall continued to use DM math time to prepare or review DM tests using the test editor in the teacher management system. Mrs. Hall rarely initiated conversations (math questions or discussions) with individual students during their ten-week implementation of DM in the Gateway lab, although she did permit students to talk quietly amongst themselves while using DM. Even though this opportunity for peer discussion was not provided in the regular math class, it is significant that it was unplanned in the context of the students' use of DM. Early conversations by students, went unadmonished by Mrs. Hall, and evolved into more frequent discussions with their peers. Students' discussions with one-another in the Gateway lab did not violate Mrs. Hall's requirement for a quiet work environment. Although the DM classroom milieu afforded students' the opportunity to interact with their peers, a certain code of student conduct remained firmly in place; students worked quietly, and productively on math tasks assigned by Mrs. Hall.

Mrs. Hall did not reach the stage of Adaptation (thorough integration) of DM during her ten-week implementation. Mrs. Hall's (three) weekly math lessons with Saxon, and her (two) weekly math lessons with DM remained exclusive enterprises for the duration of the implementation. Mrs. Hall's use of DM was temporally and spatially isolated from the regular math class. She continued to use the DM system to reinforce or supplement math concepts previously learned by students using the Saxon scheme, but not to teach new concepts, or replace lessons in the traditional text. Students' use of DM was not discussed in the regular math class, nor did students access the RVDP system using Mrs. Hall's classroom computer during the regular math lesson. Research suggests that these follow-up activities that supplement students' learning with innovative educational technologies actually assist students in applying what they've learned in new situations thereby extending their learning (Barron et al, 1995).

The Implementation Impasse

The highest level of implementation achieved by Mrs. Hall is represented by Point D in Figure 7. This was the point beyond which Mrs. Hall's implementation of the RVDP innovation could proceed, but her instructional practices could not evolve or progress. I refer to this point in the implementation process as the *Implementation Impasse*. Why did Mrs. Hall's instruction in the DM math class not evolve beyond Sandholz et al.'s (1997) stage of adoption?

Simultaneous Implementation of Oppositional Curricula

The challenge facing Mrs. Hall at the outset of this research, was not simply one of implementing a new math curriculum in the form of an interactive learning system, but rather one of simultaneously implementing two diametrically opposed curricula: the Saxon math scheme and the DM innovation. In Mrs. Hall's case, progression along the instructional change continuum was incumbent upon her ability to reconcile her use of these two curricula to teach math. A brief comparison of Mrs. Hall's regular math scheme (Saxon) and the novel math scheme she implemented (DM) is provided in Table 17:

Table 17

Comparison of Regular and Novel Math Curricula

Saxon Math and Destination Math	
Aligned with standards	
Comprehensive, complete math curricula	
Saxon Math Scheme[a]	**Destination Math**[b]
District mandated	District supported
Adopted district-wide	Adopted early by Mrs. Hall
Basic math curriculum	Optional basic or supplemental curriculum
Prescribed, sequential lesson plans	Optional lesson plans
Prescribed lesson format	Suggested lesson format
Traditional instructional media (text, chalkboard)	Novel instructional media (interactive learning system)
Familiar classroom environment	New computer lab environment
Curriculum control	Optional teacher and, or, student curriculum control

Note. [a]Implemented for one 40-minute class period, three times weekly, [b]Implemented for one 40-minute class period twice weekly.

The Saxon and DM math curricula can be distinguished in terms of some obvious dualisms: familiar versus unfamiliar; prescribed versus optional; and curriculum-controlled versus teacher, and, or student controlled. These two curricula derive from oppositional epistemologies and exhort contrasting methodologies:

1. The Saxon scheme prescribes routine textbook driven teacher-lecture and student recitation and seatwork. This approach suggests that math

knowledge resides in the textbook, although the student may come to share in this knowledge through hard work and honest effort.

2. The RVDP interactive learning system does not prescribe an optimal course toward math learning. The teacher and, or, student may choose from the available math resources and thus decide which knowledge is of most worth. This approach suggests that knowledge resides in the interactive learning system (DM curriculum), the realm of real world problems (RVDP news archives), and can be created by the learner (TM open-ended tool-based system).

Saxon's claim to the universality of their math textbook scheme is evident in their call for seamless and programmed implementation of pre-scripted texts -suitable for all students, and all teachers, in all schools. The recommendation by Saxon that the sequence of their lessons should be uninterrupted by alternative texts or variable use, suggests an objective certainty characteristic of *modern texts*. In contrast, the selection of resources provided by the RVDP interactive learning system, implies a rejection of the instructional metanarrative (Ozmon & Craver, 1992, p. 380) exhorted by Saxon. Spring (1991) explained, "Knowledge is not neutral. By presenting the reader with a compendium of information, the modern textbook, in contrast to the postmodern textbook, conveys the impression that scholars agree on a particular body of knowledge" (p. 262). The assortment of math activities made available by RVDP (news articles, open-ended learning tools, and the scenario-based math curriculum, DM, in addition to interdisciplinary resources on the RVDP web-site), represent varied design styles and dynamic representations of knowledge, which support diverse instructional uses. The

RVDP resources afford multiple representations of content and creation of content by students and teachers. By focusing on this diversity (of activities and implementation options) the RVDP learning system can be described as a *postmodern text*.

To successfully implement DM, Mrs. Hall is expected to faithfully use the Saxon regime on Mondays, Tuesdays and Fridays, and to believe in the DM learning system on Wednesdays and Thursdays. Mrs. Hall's lack of knowledge of the RVDP system impeded her ability to compare this novel educational technology with her regular math curriculum, prior to, and during, the implementation process. Given opportunities to explore and compare both curricula, the complex instructional transition required of this teacher would have become more transparent to Mrs. Hall, thereby enabling her to make informed choices regarding her implementation the RVDP learning resources.

In-Flight Standards-Aligned Curriculum Design

Assuming that Mrs. Hall had made an informed decision to implement the RVDP resources in tandem with her regular math curriculum, successful implementation would have required her to engage in adequate planning activities. Effectively, Mrs. Hall would have been required to design a new curriculum to maximize the interoperability of both math schemes. (*When* was Mrs. Hall expected to do this?) This new curriculum would have been aligned to the state standards for math in order to adequately prepare Mrs. Hall's students for the eighth grade PSSA math test. (*How* was Mrs. Hall expected to do this?)

Both the Saxon and RVDP math resources had been adopted by the Westridge School District administration to improve eighth grade students' scores on the PSSA math test. Touted as a veritable standards machine by teachers and administrators at

Westridge, the Saxon math scheme prepares students to meet the NCTM standards, the National Standardized Tests (SAT 9, ITBS, Terra Nova) and the State standards (including the Pennsylvania Academic Standards for Mathematics [PASM]) by prescribing sequenced, self-contained math lessons organized as inclusive text-based math curricula[26]. Mrs. Hall explained that teaching with Saxon, had become synonymous with teaching to the test. To successfully accomplish both, Mrs. Hall's instructional practices had been reduced to a set of routine, mechanistic, programmed steps:

> The program is scripted so teachers know exactly what to say and how to say it… The difficult work of lesson planning is already done for teachers. The highly structured approach of the Saxon programs makes them very teacher-friendly… substitute teachers can step in and continue the flow of lessons without interruption. Some teachers have even expressed guilt about not having to do as much since they began to use Saxon. (Saxon, 2001, para. 3 and para. 4)

Curriculum control is a key subtext of the standards-based Saxon regime. The endorsement of state-mandated high stakes testing by policymakers and politicians has legitimated the specification of instructional objectives and methods within self-contained curricula (such as the Saxon scheme) and resulted in the commodification of teachers' instructional practices. As an eighth grade teacher using Saxon at Westridge, Mrs. Hall was in the business of preparing her students to take, and successfully pass, a state test for math. "By definition, standardizing curricular ends requires specifying, behaviorizing and particularizing what can be measured and (hopefully) controlled … in the teaching-learning process" (FitzPatrick, Marshall, Nelson and Park, 2000, p. 31). The Saxon publishers in Norman, Oklahoma had determined the most appropriate

[26] Endorsement of the totalitarian Saxon curriculum at Westridge Junior–Senior High School is such that Mrs. Hall's math classes or courses are denoted by the name of the Saxon text used: Math 76, Math 87.

instructional objectives and practices for both of Mrs. Hall's eighth grade math classes in Milton, Pennsylvania. Mrs. Hall had been removed from the realm of curriculum deliberation. Mrs. Hall's professional knowledge landscape, that place of decision-making "positioned at the interface of theory and practice in teachers' lives" (Clandinin and Connelly, 1996, p. 24) had been made redundant in her math teaching. Mrs. Hall's success as a math teacher was hinged on her ability to execute standards-based curricula by following programmed lists of instructions prescribed by the Saxon publishers. In implementing the Saxon regime, the essence of Mrs. Hall's role as a teacher had been called into question:

> The essence of being a teacher is knowing who you are, where you are - and liking what you find. Being a teacher means being able to draw your own map – instead of relying on mass-produced tourist guides. Being a teacher means understanding that the best map you draw still is not the territory. (Ohanian, 1999, p. 151)

<u>Re-Skilling without Support</u>

Successful implementation of RVDP resources with both eighth grade math classes would implicitly have required Mrs. Hall to design new instructional maps using these multiple curriculum resources. Mrs. Hall would have had to develop these curriculum design skills during her one preparation period in the day (assuming she had no other pressing or more urgent duties or tasks), or during her own personal (evening) time, and in either case, with minimal support.

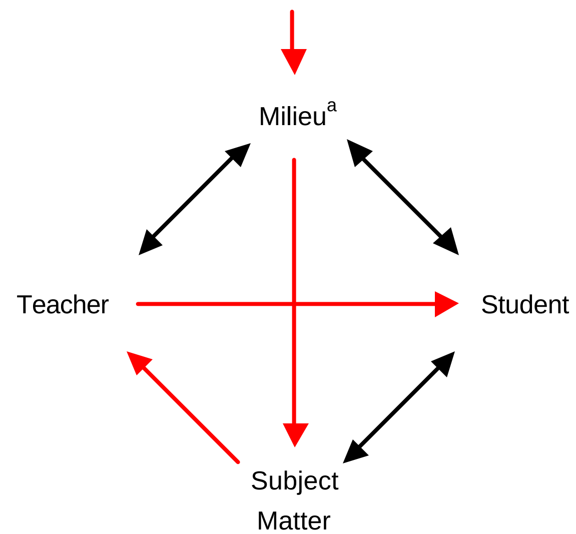
The two factors most frequently cited by Mrs. Hall as impeding her implementation of the RVDP resources were lack of time and lack of knowledge. Mrs. Hall's desire for in-school professional development opportunities to assist her in implementing DM was evident during this 14-week implementation. Following her three-hour professional development session with the RVDP implementation specialist, Mrs. Hall became excited about the possibilities for teaching and learning with the RVDP resources. These supportive conditions (allocation of time, development of knowledge) were not sustained during Mrs. Hall's implementation of DM. Paradoxically, Mrs. Hall was to teach students how to use the RVDP innovation, without first having learned to use it herself. The resources available to Mrs. Hall during this implementation process: technical support, and on-line and text-based RVDP teaching resources (user manual, activity notebook), were rarely utilized by her. Sustained professional development opportunities, would have targeted support to Mrs. Hall's particular needs and concerns during this implementation process. Consistent support, by way of professional development, for Mrs. Hall throughout the implementation process would most likely have made these available resources *accessible* to Mrs. Hall and would have supported her instructional efforts to implement the RVDP resources.

Aligning Instructional Objectives: Exploring Curriculum Control

The Westridge School District adopted Both the Saxon Math scheme and the RVDP interactive learning system with the explicit purpose of improving their eighth grade students' scores on the PSSA math test. Although Mrs. Hall initially expressed her expectations for implementing the RVDP resources with her two eighth grade classes (personal renewal and increased student interest in math), she did not articulate a specific set of instructional objectives for her use of this novel educational technology. Mrs. Hall implemented DM as an extension of her classroom practice: rigorous testing and reinforcement of core concepts. This teacher implemented in ways that were consistent with her school's goals, and her past experience with the regular math curriculum.

While Sarason (1990) has claimed that the structure of students' learning is a derivative of the power of the teacher; "the teacher has the power to alter, even radically, how learning is structured" (p. 89), this research suggests that the structure of a teacher's teaching is a derivative of the power of the school administration. Mrs. Hall taught with a district-mandated curriculum, selected by the school administration to improve eighth grade students' math scores. Traveling along the continuum of school influences, one could argue that the structure of a school administration's administration is a derivative of the power of the political forces shaping educational policy, evident in the imposition of national and state-mandated curricula and testing.

The Westridge School District initially adopted the teacher-proof Saxon curriculum to improve their students' eighth grade scores on state-standardized tests. The goals (why), content (what), and methods (how) of instruction are prescribed by Saxon within self-contained sequenced lessons organized by text-based course level. Years spent using the Saxon regime with her eighth grade math classes had deprived Mrs. Hall of many of the routine decisions one would expect a teacher to make within the course of planning for, and teaching, students. Cuban (1993a) suggested that management controls on teaching (e.g., standards and standards-based curricula) have duly worked their influences in "shaping a durable, practical pedagogy, called teacher-centered instruction" (p. 260). Mrs. Hall's teaching with the Saxon math series, can be crudely described as teacher-centered. McNeil (1986) explained that increased management controls (in the form of district-mandated curricula, etc.) regarding what constitutes appropriate subject matter in schools, trickle through the education system and result in increased controls on students' learning Mrs. Hall's students, the recipients of the mandated Saxon curricula, perceived that they had little control over their own learning in the regular math class. The direction of curriculum control within Mrs. Hall's regular math class is explored in Figure 8.



[a]School Milieu

Figure 8. Curriculum Control In Mrs. Hall's Regular Mathematics Class

Figure 9 further explores the student and teacher transition from the regular Saxon math class to the DM math class by focusing on the measure of curriculum control exhorted by teachers, students, subject matter, and school milieu in the DM math class. In contrast with Figure 8, Figure 9 represents the diffusion of curriculum control in Mrs. Hall's DM math class. Curriculum agency was shared among four curriculum contexts: the school administration, the teacher, the DM interactive learning system, and the students:

1. The Westridge School District adopted the RVDP interactive learning system with the goal of improving eighth grade student achievement on statewide math testing
2. Mrs. Hall chose the content (Course IV) and the instructional methods (tests, prescribed assignments) for her students' use of DM
3. DM offered a range of methods or instructional agents for exploration of different levels of math content.
4. Students chose to regulate the content and the methods of instruction in accordance with their own pedagogical preferences

In the DM math class, Mrs. Hall was expected to make decisions about curriculum in a new context of shared curriculum control. In making these decisions, Mrs. Hall began to reassert her role as teacher within a new curriculum context -one in which she could no longer be expected to know or control the flow of information to the learner (Boethel & Dimrock, 1999). The students' participation in leveraging control over their classroom learning in math, enabled them to make decisions about their own instruction, decisions we generally defer to the traditional role of teacher in the teacher-learner interaction.

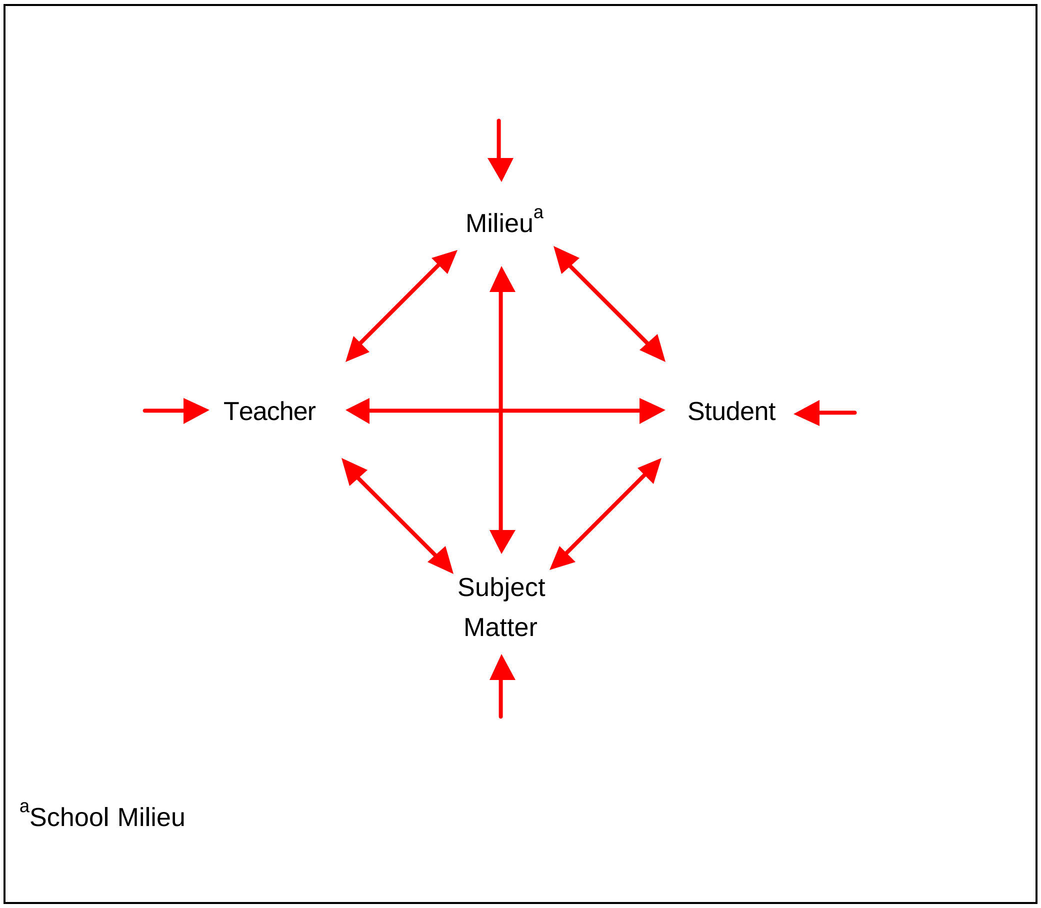


Figure 9. Curriculum Control In Mrs. Hall's DM Class

Students' Experiences with DM

Despite Mrs. Hall's attempts to structure her students' learning with DM by specifying content (Course IV, Fractions, etc.) and instructional methods (tests, prescribed assignments), her students experienced a level of autonomy over their own math learning that they had not experienced in their regular math class using Saxon. Control is relative. Mrs. Hall's students spoke positively about the level of learner control afforded to them in the DM math class. Students who completed their DM tests and prescribed assignments within the class time could access math modules, units and sessions (content), and reports, tutorials, workouts and practice problems (instructional methods) of their choice. Students' primary experiences with DM focused on the level of choice it afforded them vis-à-vis the content and methods of instruction, and the social context for these activities: the opportunity to interact with their peers. Students experienced increased motivation in math as a result of their experiences with DM.

Activity Choice

Mrs. Hall's students frequently spoke about the variety of activities available to them using DM. Students worked independently, and in collaboration with others seated nearby, to explore the range of tools available in DM. Students commended their own abilities to make good choices and purposefully navigate the system. My own observations of student work supported their self-reports. Student engagement with math during the DM lesson -operationally defined as time-on-task, remained consistently high in the DM class, throughout the ten-week implementation of DM.

This finding sharply contrasts students' low levels of time-on-task in the regular math class observed prior to, and during, the implementation of DM. Students had few, if any instructional choices within the regular math class; their time on task during researcher observations remained consistently lower than in the DM class. This research suggests that the level of choice afforded to students by an educational technology is positively related to their level of engagement with the subject matter, made visible by high levels of on-task behavior.

Feedback and Reports

Mrs. Hall's students were not instructed or encouraged to use the DM test feedback, test report, or progress reports in the Gateway lab. Students discovered and employed these tools to review, reflect upon and regulate their math learning with DM.

Students who scored their math test used instantaneous test-feedback to compare their own answers to test questions with the correct DM responses provided. The correct-answer feedback provided by DM enabled students to identify the source of their errors by reviewing and reinterpreting both the test question and their own problem solving strategies. Students learned to troubleshoot their own responses to test questions. They used this information to learn from their mistakes. Clariana (1993) compared the effectiveness of two types of feedback with eleventh grade students; answer-until correct (AUC) feedback, and knowledge -of-correct-responses (KCR) feedback. KCR feedback provided the learner with the correct answer to the problem after one missed attempt. Clariana found that KCR students significantly out-performed students receiving AUC feedback. The KCR feedback provided information that students could use to clarify misunderstandings of what they had read. Similarly, Mrs. Hall's students used the DM show-me button to receive immediate assistance in resolving math workout problems. They then used this information to solve successive problems.

Information provided in the test report (percentage score, number of correct, incorrect and attempted problems) enabled students to see beyond the final math score to their performance on individual learning objectives assessed within the test. Students also learned to use the progress report data provided (e.g., percentage of problems correct for each activity, amount of time spent on each activity, and date the activity was completed) to identify gaps in their progress, plan make-up work and navigate the activity options within DM. Students frequently used these accessible and transparent reports of their DM work to critically appraise their own progress with the learning system.

Students' sophisticated use of feedback and report tools to effectively regulate their own learning in the DM class suggests that learners can develop the skill and will (McCombs & Marzano, 1990) to manage their own learning, given educational technologies which provide detailed, accessible, and instantaneous feedback to students regarding their progress. Students' efforts to self-regulate in the DM class also represent an increased interest in, and concern for, interpreting, analyzing, and improving their own math performance. Students used these flexible and versatile DM tools to individualize their math learning, thereby experiencing a universally designed approach to curriculum and learning with DM (CAST, 2000). Mrs. Hall's reluctance to explore and experiment with DM reports and feedback tools, contrasts with her students' purposeful use of the information provided. Students used the DM test reports and feedback tools in ways we would expect a teacher to. These tools afforded students opportunities to evolve into roles they had not assumed in the regular math class.

Representation of Math Concepts

Students who completed their tests and prescribed assignments could choose the instructional representation of math concepts in DM, primarily tutorials (options to repeat the problem explanation, receive a partial or complete explanation of the problem, receive practice problems) or workouts (problem area option). Both Mrs. Hall and her students noted that the fantasy characters and realistic scenarios increased students' interest in the math problems provided in DM tutorials and workouts. When asked, students' consistently reported that the use of scenario contexts improved their appreciation of the relevance of math in the world. This research suggests that design features which afford fantasy characters and realistic scenarios that are interesting and appealing to students, may improve their interest in math, and their understanding of math use, in a variety of everyday contexts.

Students frequently noted the benefits of the multiple pathways to learning (text, graphics, speech) provided in each DM tutorial and workout explanation. They suggested that these three modes for representation of problems were motivational in and of themselves. Hannafin and Sullivan (1995) also found that students using either *text-plus-static graphics* or *text-plus-animated graphics* methods for presentation of math topics, expressed a more positive attitude toward math than those who viewed the text-only version. Moreno and Mayer (1999) compared the performance of sixth grade students using single-representation (SR) and multiple-representation (MR) versions of a computer-based multimedia program on addition and subtraction of signed (positive and negative) numbers and found that that the benefits of using MRs for example problems were strongest on difficult problems. In the present study, students who used DM indicated that the multiple representations of content were especially helpful in enabling them to analyze and complete difficult word problems. Additionally, students noted that the character voices and colorful graphics in DM engaged their interest during their completion of these problem tasks.

Students' varied use of these multiple representation formats for learning, coupled with their independent and collaborative use of DM, suggest that the educational technology provided, facilitated diverse learning style preferences among students. "People are different, and it is good practice to recognize and accommodate individual differences. It is also good practice to present information in a variety of ways through more than one modality…" (Snider, 1990, p. 53). The flexibility of the educational technology in facilitating multiple combinations of use (content, instructional method, multiple pathways) enabled students to learn in ways that supported their own pedagogical preferences.

Peer Interactions

The DM lesson also afforded students the opportunity to interact with their peers while learning math. In the regular class, students would quietly complete their practice set following Mrs. Hall's correction of homework and presentation of the new increment. In the computer lab, students could choose to speak quietly with those working near them. Mrs. Hall neither provided guidelines regarding whether or not students could interact with one another in the lab, nor organized formal groups or pairs of collaborators. Students spontaneously devised strategies that enabled them to complete math activities and engage in math talk with their peers.

Many students made exhaustive efforts to synchronize their use of DM tutorials, workouts and tests with those students seated on either side of them. Students who coordinated their pacing of DM activities in this way consistently demonstrated high levels of interest and enjoyment in the math activity which often proceeded in game-like manner with frequent choruses: “Ready, Set, Go!” “One, two three!” “Marks, set, go!”

Students regularly engaged in various forms of math-talk with their peers during the DM lesson, frequently offering or receiving assistance with a math problem. Students were more likely to seek help from one another than from Mrs. Hall during the DM lesson. Students began to support each other in various ways (advising, assisting, coaching). Means and Olson (1995) suggested that collaboration among students using educational technologies was possibly a function of the instructional medium (the educational technology) itself:

> Students’ coaching roles were generally not something that teachers had set up in any formal way, rather they emerged naturally as part of the parallel technology-based activity in the classroom. Several teachers remarked that the technology stimulated much more advice seeking and giving among students. (p. 142)

This claim is not warranted within the present study. While the milieu for math learning in the Gateway Lab was significantly different from the students’ experience of math learning in the regular math class, these changes cannot be attributed to the change in subject matter (represented by the implementation of DM) alone. The physical transition from Mrs. Hall’s regular math class to the shared Gateway lab, the use of mobile chairs instead of study-top desks, the layout of computer workstations, the lack of enforced rules or regimens, and the addition of two adults (Mr. Mercer and myself, the researcher) to the math lesson, most likely supported peer collaboration within the DM math class.

Students' discussions of math while using DM frequently progressed through a sequence of stages including: advice-giving, advice-seeking, evaluation, comparison, clarification, acceptance or rejection of alternative rationales, and defense of math claims or assertions. Students frequently attempted to persuade their peers that certain choices or decisions were preferable to concurrent choices or decisions (Perelman, 1980) in resolving math problems. By engaging in this form of math argumentation, students were frequently required (by their peers) to provide support and justification for their assertions and claims using data, facts and evidence (Toulmin, Rieke and Janek, 1984).

Students in Mrs. Hall's classes enjoyed learning math with their peers. Many students indicated that the *quality* of the math experience improved significantly when they had opportunities to work with one-another, and make instructional decisions. While learner control has generally been used to refer to the delegation of instructional decisions to learners "so that they can determine what help they need, what difficulty level or content density of material they wish to study, in what sequence they wish to learn the material, and how much they want to learn" (Johnson and Johnson, 1996), this research suggests that learners' decisions regarding *how they wish to learn the material* (independently or with a chosen peer) are also critical to our understanding of how learner-control evolves during the implementation of educational technologies in classrooms. A classroom milieu that affords opportunities for students to interact with one another may increase the effectiveness of learner-control with educational technologies. Although previous studies suggest that student performance improves in learner-controlled and cooperative learning environments (McDonald, 1993; Hooper, Temiyakarn, and Williams, 1995), few studies have explored learner-control in classroom environments that afford but do not specify the structure or make-up of cooperative groups. Further exploration of students' math talk would inform our understanding of how students support one another in developing learner-control strategies during the initial implementation of educational technologies in their classes.

Student Motivation

During pre-implementation focus group interviews, Mrs. Hall's students expressed positive attitudes toward the use of educational technologies at home and at school. In culminating focus group interviews, students suggested that the educational technology, the *instructional medium*, was motivational to them, in and of itself. Students high levels of motivation using DM, are viewed in light of their low levels of interest in math in the regular math class, and their dislike for the regular (Saxon) math curriculum.

Mrs. Hall's students frequently compared the *variety* of activities afforded by the DM learning environment with the monotony of the regular math class. Students contrasted the dynamic representation of DM math concepts (graphical animation), the multiple methods for representation of concepts (text, audio, speech), and the scenario-based math problems, with the static problem sets assigned in each daily Saxon math lesson. Lepper (1980) noted that educational technologies were motivational learning tools when they were sufficiently challenging for learners, aroused curiosity and provided a sense of individual control and mastery over the environment. Mrs. Hall's students claimed that the detailed, step-by-step explanations provided in DM tutorials were particularly motivating, especially given the option to repeat the problem explanations.

Students also insisted that DM activities were especially motivational in affording a level of *learner-control* that they had not experienced in the regular math class. Students who completed their tests and prescribed assignments used DM to control the content and the representation of math concepts. Hannafin and Sullivan (1995) also found that high-school students who used learner-controlled versions of an introductory geometry software program expressed more positive attitudes toward math learning than students who used program-controlled versions of the same program.

The instantaneous feedback and progress report tools increased students' sense of efficacy and success with their own learning while using DM. Students' use of the feedback and report tools to evaluate their learning and navigate the DM activity selection, also increased their feelings of *self-efficacy*. Students discovered and learned to navigate their options within the DM math environment. Students claimed they were better able to concentrate on the math problem, and were more productive using DM than in the regular classroom.

When queried, students noted the increase in both their interest in math and their appreciation for the *relevance of math* in the real world while using DM. Existing research supports students' use of educational technologies to increase their interest in specific subject matter. Webster (1990) found that fifth grade students in rural Mississippi who received supplemental CAI expressed significantly more positive attitudes toward math than similar students who did not receive CAI. Similarly, Yusuf (1995) noted that students receiving logo-based instruction demonstrated significantly more positive attitudes toward geometry and toward math in general.

Students in Mrs. Hall's class expressed their genuine interest in, and enthusiasm for, using the DM system to learn math with frequent queries regarding whether or not it was lab day, or when the next lab day was scheduled. Additionally, a number of students explained that they looked forward to coming to school on Wednesdays and Thursdays, because they got to use DM in the lab. When asked how they felt about using DM, students invariably responded that it was just great "fun", or made math "funner".

Similarly Sandholz and her associates explained that after years of experience with educational technologies in classrooms, ACOT teachers noted students' increased motivation and interest in schoolwork. Using observational and interview data from case studies of intensive computer-using classes at reform-oriented schools over three years, Means and Olson (1995) also found that "the most common, in fact -nearly universal teacher-reported effect on students was an increase in motivation… motivation with respect to working in a specific subject area… general motivational effects… the sense of accomplishment and power gained in working with technology" (p. 149).

This research supports the claim that students' interest in educational technologies creates a powerful motivational set for their use of these instructional tools to support classroom learning. Students experienced high levels of learner control given the variety of activity choices afforded by the instructional medium, and the opportunity to discuss and complete tasks with their peers. Students' interest in math, their understanding of the relevance of math, and their feelings of self-efficacy with math, increased during the implementation of this educational technology in their math class. These findings suggest that students' increased interest in subject matter while using an educational technology, may transfer to increased motivation toward school learning in general.

Conclusions

This research provided a snapshot of the experiences of one teacher and her 32 students during the process of implementing an educational technology in their math class over a fourteen-week period in Spring 2001. Findings suggest that the transition from an externally-controlled, teacher-proof curriculum (Figure 8) to one that affords measures of instructional control to teachers and students (Figure 9), is an extremely complex one. While students readily assumed new instructional roles, given the level of learner-control afforded to them by the novel educational technology, the teacher's instructional practices did not evolve beyond the use of the innovation to replicate traditional instructional practices and meet pre-determined school goals.

Conditions that supported the teacher in her decision to adopt the educational technology curriculum innovation did not sustain her instructional evolution during the implementation process. The greatest impediment to instructional change for the teacher was that of simultaneously implementing two epistemologically and methodologically oppositional curricula (the traditional teacher-proof math text, and the resource-based interactive learning system), with inadequate support. Given this mismatch (instructional objectives and methodologies) between traditional and novel curricula, and minimal support for implementation, this research suggests that a teacher's instructional model may change slowly, or may change very little, over the course of a school semester. The research on teacher change and instructional reform in general, supports this finding that changes in teacher practice are often slow, minimal, or even non-existent (Smerdon et al., 2000, p. 3). Change researchers (Fullan, 1991, Hall and Hord, 2001) add that the implementation of change may often take from three to five years. This research has shown that progression beyond the stage of innovation adoption to adaptation represents a complex yet critical transition, during a teacher's implementation of educational technologies, one which may be determined by the level of support provided to the teacher prior to, and during the implementation process.

While the teacher's primary experience with the educational technology focused on her use of the management tools to generate student tests and prescribed assignments, the students' primary experiences focused on learner-control: choice of math content and instructional strategies, and the option to engage in spontaneous math conversations with their peers. Students were highly motivated during their use of educational technologies: engagement with math, defined operationally as time-on-task, began and remained high during the course of the study. Students learned to use the tools of the system to regulate their own learning during the implementation process. At the conclusion of the research, the students overwhelmingly indicated their desire to continue their use of the interactive learning system for math, while the teacher planned to reduce her use to one class period per week, or less.

Recommendations for Future Research

- More long-term research is needed to explore conditions (teacher, local and external) that support changes in a teacher's pedagogical practices during this decisive transitional stage in the implementation process. How do teachers' needs for instructional support evolve during the implementation process? What supports do teachers receive? Which supports do teachers perceive as critical to the success of their implementation of educational technologies in their classes?

- More in-depth research on teacher's perceptions of, and reflections on, the change process would enlarge our understanding of change or evolution in teachers' professional landscapes during the implementation of educational technologies. How do teachers' professional landscapes change or evolve during the implementation of educational technologies in their classrooms? How do teachers perceive their own roles? What theories do teacher's draw on to inform their classroom practice during the implementation of educational technologies?
- Exploration of change in students' and teachers' perceptions and experiences of instructional agency during the implementation of educational technologies would enable us to envision new roles and responsibilities for teachers and learners in technology-enhanced learning environments, and provide adequate support for these roles. How do participants define their roles as instructional agents within the classroom? What change in role do teachers and students expect or anticipate with the advent of educational technologies? What changes do they experience? How do they define these transformations?
- Within school systems, exploration of the experiences of various individuals (administrators, teachers, staff, students) during the implementation of educational technologies in their schools and classrooms, would enable us to explore complex interrelationships between implementation contexts within and beyond the classroom in much greater detail, than in the present study. How do teachers and administrators envision change prior to, and during the implementation of educational technologies? How do participants redefine curriculum within this change context? How do participants' perceptions of the

goals, methods and content of curriculum relate? How do teachers' goals for their use of educational technologies compare with those articulated within school mission statements, and organizational goals? How do the visions or expectations for educational technologies within schools change, in different contexts?

- Further exploration of students' (math) talk while using educational technologies for classroom learning, would inform our understanding of how students support one another in developing learner-control strategies during the initial implementation of educational technologies in their classes. What strategies do students adopt or create to manage their own learning using linear and open-ended learning systems? What features of the learning tools and affordances in the local environment do students use to direct their own learning? How do students feel about their abilities to control their learning?

Recommendations for Implementation of Educational Technologies

By exploring the implementation of an interactive learning system as an episode of curriculum change, this research has shown that understanding the match or mismatch between epistemologies, pedagogies, institutional support, and goals for existing school curricula and proposed educational technology curriculum innovations, is a critical first step in understanding the human process of implementing educational technologies. I presented four reasons for the lack of any significant teacher change during this implementation research:

1. The challenge of simultaneously transitioning between two (traditional and novel) curricula which espouse contrasting epistemologies and methodologies

2. The challenge of designing a new curriculum which maximizes the interoperability of the traditional and novel curricula, and addresses educational standards
3. The challenge of implementing novel instructional curricula with little support; time and knowledge of the innovation emerged as critical factors.
4. The challenge of transitioning from a tightly controlled (standards-aligned, teacher-driven) curriculum to one that supports shared curriculum control (among school administrators, teachers, students and subject matter).

In the present study, lack of knowledge of the innovation, and time to learn about the innovation, were identified by the teacher as the greatest impediments to her implementation of the educational technology with her students. At the outset, Mrs. Hall was not involved in identifying or selecting the innovation she was expected to implement. Professional development opportunities were not available to her during the implementation process. While Mrs. Hall had administrative and technical support, she did not have opportunities to share the implementation stories of colleagues. A robust plan to support teachers' implementation of educational technologies should:

- Involve individual teachers, or teams of teachers, in the identification and selection of educational technologies for implementation within their classrooms
- Provide frequent and ongoing opportunities for professional development (within school time) prior to, and during, the implementation process. This professional development support should provide teachers with opportunities to meet with each other, and periodically meet with administrators to:
  - Reflect on and describe their current instructional goals and methods

  - Envision a role for the technological innovation within this professional framework, and articulate instructional goals for the use of the innovation
  - Discuss their instructional goals for educational technologies vis-à-vis the school culture: mission statements, existing curricula, etc.
  - Develop a comprehensive technology implementation plan
  - Encourage teachers to develop local measures of assessment to assist in determining how to evaluate the effectiveness of the particular innovation
- Involve teachers in action-planning and decision-making processes regarding the implementation of educational technologies in their schools and classrooms
- Foster mentoring among teachers with varied levels of experience using educational technologies within and among schools

This research explored the experiences of one teacher and her students during their implementation of an educational technology innovation in their eighth grade math class. Schwab's four contexts provided a useful framework for exploring the teacher and her students' actions and interactions with DM, within the conditions afforded by their classroom and school milieux.

The present study cautions that the level of match or mismatch between *expectations* of, and actual *conditions* for, the implementation of novel educational technologies by teachers may profoundly affect teachers' and students' experiences of these innovations in their classrooms. The sagacity of employing novel educational technologies to achieve narrowly defined school goals already articulated, and targeted, by established school curricula is questioned. In a time of heightened expectations for the transformation of learning environments by novel educational technologies, this research exposes the soft underbelly of teacher-proof curricula, and the seductive deskilling of teachers, as mitigating factors within this climate of anticipated instructional change.

In the present study, the level of curriculum control afforded to both the teacher and her students by the RVDP educational technology was found to be a critical factor influencing participants' experiences and perceptions of this curriculum innovation. The teacher had been ill-prepared to assume instructional control and share it with students, while the students welcomed the transition to what they perceived as a learner-controlled environment.

The call for ongoing, sustained professional development and administrative support for teachers (prior to and during their implementation of educational technologies) is made in light of the teacher's decision to lessen her use of the educational technology in her math classes, despite the significant and tangible benefits for her students.

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Appendix A: Organization of Destination Math Content

Table 18

Organization of DM Content

Grade Levels[a]	Series	Course	Modules
Upper Elementary School Grade Levels	Mastering Skills & Concepts	Course III	Numbers & Number Sense Operations with Numbers Fractions Decimals Geometry Data Analysis & Probability
Junior High/Middle School Grade Levels	Mastering Skills & Concepts	Course IV	Fractions Decimals Percents Integers & Order of Operations
	Mastering Skills & Concepts	Course V	Essentials of Algebra Fundamentals of Geometry Radicals and Exponents Ratio and Proportion Fundamentals of Statistics Fundamentals of Probability
High School Grade Levels	Mastering Algebra	Course I	The Language of Algebra Linear Functions & Equations Systems of Linear Equations Linear Inequalities
	Mastering Algebra	Course II	The Real Number System Powers & Polynomials Quadratic Functions & Equations Algebraic Expressions & Functions Describing Data

[a]This column represents recommended grade levels

Appendix B: Classroom Observation Protocol I: Classroom Map

CLASSROOM MAP

Class Session

Class Group: ____________________

Classroom: ____________________

Instructor: ____________________

Session: ____________________

Date: ____________________

Time: ____________________

Classroom Layout

Include:

- Furniture
- Storage areas
- Learning resource areas
- Computer resources
- Riverdeep resource centers
- Teacher resource area
- Whiteboard or equivalent
- Wall-mounted materials
- Noticeboards
- Classroom Entrance/Exit

Appendix C: Classroom Observation Protocol II: Activity Framework

ACTIVITY FRAMEWORK

Class Session

Class Group: ________________ **Classroom:** ________________	**Instructor:** ________________ **Session:** ________________	**Date:** ________________ **Time:** ________________

Activity Overview

WHAT Activity/Task	**WHEN?** Activity Duration	**WHY?** Activity Rationale	**WHERE?** Activity Areas	**WHO?** Activity Participants

Appendix D: Document Analysis Protocol

Document Description	
WHAT? *Document Type*	
WHEN CREATED? *Date Document Created*	
WHEN FOUND/RECEIVED? *Date Document Found*	
BY WHOM? *Document Producer*	
FOR WHOM? *Document Audience*	
WHERE? *Document Location*	
WHY? *Purpose of Document*	
OTHER COMMENTS	

Appendix E: Semi-Structured Teacher Interview I

The following interview guide will be used to conduct the first, semi-structured interview with the teacher. This interview is scheduled for approximately 35-40 minutes.

Introduction: The teacher is thanked in advance, for giving of her time for this interview. The researcher invites, and answers, any new questions about the research purpose, focus, or future directions.

TEACHER IDENTITY

Can you tell me about your math-teaching career, here at Westridge High School?

- Duration
- Students and topics taught
- Special activities

MATH PLANNING

Would you describe the process of how you go about planning your math lessons?

- Formulation of learning objectives for students
- Macro-level planning
- Micro-level planning
- Teacher accountability

PREVIOUS EXPERIENCE OF USING TECHNOLOGY IN MATH

What computer-based mathematics resources are you familiar with?
Have you used any of these tools to teach math in your eighth-grade classes?
How did these tools change the way you taught math?

- Changes in planning?

How effective do you think these learning tools have been?
Which learning tools have you been most satisfied with? Why?

- Features of learning tools

Do you think students found these tools effective in learning math?

- Changes in learning activities

PERCEPTIONS OF USE OF RIVERDEEP INTERACTIVE LEARNING RESOURCES

What do you know about Riverdeep interactive learning resources?
How do you feel about implementing these resources in your math classes?
How do you plan to use these resources in your math class?

- Classes and student groups
- Tools to be used
- Anticipated frequency of use

Do you think these resources will alter the way you plan your math lessons?

- Organization and sequencing of content?
- Learning objectives?

- Student grouping structures?

Do you expect the use of RVDP materials to change your role as teacher in the classroom?

- Assumed teacher roles

Conclusion: The teacher is asked to contribute any other thoughts or ideas regarding the implementation process or the research. The teacher is thanked again for her willingness to be involved in this research.

Appendix F: Semi-Structured Teacher Interview II

The following interview guide will be used to conduct a second, individual semi-structured interview with the class teacher. As before, this interview will be scheduled for approximately 45-55 minutes.

Introduction: The teacher is thanked in advance, for giving of her time for this interview. The researcher invites, and answers, any new questions about the research purpose, focus, or future directions.

TEACHER EXPERIENCES WITH DM

Could you describe your experience with the Destination Math program in your eighth grade math classes?

- Use of the student data management tools
- Selection of student tests
- Reporting of student tests
- Prescribed assignments
- Tutorial and workout activities
- Likes and dislikes

STUDENT EXPERIENCES WITH DM

How do you think the students are responding to the use of Destination Math twice each week?

- Student learning and progress
- Student time-on-task
- Student interaction with peers
- Student interactions with tools of learning: computer, menu items, calculator, etc.
- Student interactions with teacher
- Student role in the classroom

CURRICULUM PLANING FOR MATH: SCOPE AND SEQUENCE

Could you talk about whether or not the use of Destination Math with your eighth grade math students has affected your curriculum planning for these students, and if so, how?

- Macro-level planning
- Micro-level planning
- Scope and sequence of topics
- Projected and anticipated planning changes

Conclusion: The teacher is asked to contribute any other thoughts or ideas regarding the implementation process or the research. The teacher is thanked again for her willingness to be involved in this research.

Appendix G: Semi-Structured (Active) Teacher Interview III

The following interview guide will be used to conduct a third, individual, semi-structured–active interview with the eighth grade math teacher. The interview occurs at the end of the research as a validation check of the research findings. It is very much an 'active interview' where the researcher invites the teacher to discuss the researcher's findings. This interview is scheduled for approximately one hour.

Introduction: The teacher is thanked in advance, for giving of her time for this interview, and for her cooperation during the research effort. The researcher invites and answers any new questions about the research purpose, focus or future directions.

TEACHING EXPERIENCES WITH DM IN CONTEXT

I've learned during my time here, that you really have a lot to contend with in planning and teaching your math classes. How does the Destination Math program, fit into this?

- Macro-level planning
- Micro-level planning
- Scope and sequence of topics
- Student Evaluation

TEACHER EXPECTATIONS FOR, AND EVALUATIONS OF, DM

You mentioned in an early interview, that you hoped Destination Math would provide some "renewal" in your teaching. Do you think it has?

- Pedagogical change and innovation
- Curricular change and innovation

DM IMPLEMENTATION PROCESS

How would you describe the implementation process?
Would you like to have changed any part of the implementation process?

- Time
- Resources
- Administrative support
- Knowledge of Destination Math

STUDENT EXPERIENCES WITH DM

How do you think the students are responding to the use of Destination Math twice each week?

- Student learning, student progress
- Student time-on-task
- Student interaction with peers
- Student interactions with Destination Math and tools of learning: computer, menu items, calculator, etc.
- Student interactions with teacher
- Student interest in math/awareness of math relevance

TEACHER EXPERIENCES WITH CHANGE

Having experienced various educational initiatives in schools and classrooms, how do you feel about educational change?

- Educational innovations
- Educational technologies

Conclusion: The teacher and researcher discuss the research findings (listed as topics, above). The teacher is asked to contribute any other thoughts or ideas regarding the implementation process or the research. The teacher is thanked again for her willingness to be involved in this research.

Appendix H: Semi-Structured Student Interview I

The following interview guide will be used to conduct the first, semi-structured interview with individual eighth grade students. This interview is scheduled for approximately 25-35 minutes.

Introduction: The student is thanked in advance, for giving of his or her time for this interview. The researcher invites and answers any new questions about the research purpose, focus, and future directions.

STUDENT ATTITUDE TOWARD MATH

Could you tell me what you think of math?

- Life-relevance
- General use
- Experience

STUDENT EXPERIENCES WITH MATH IN SCHOOL

If you think about your experiences learning math in school, can you tell me the highlights -what you most like about learning math in school, and also those things you least like.

- Subject matter: Preference for learning specific math concepts
- Methods: Preference for learning with specific media

STUDENT EXPERIENCES WITH DM

Could you talk about what you think of using Destination Math to learn math in school?

- Learning math concepts, problem solving
    - Explanations (tutorials, show me supports)
    - Examples (scenarios, stories)
        - On-line tools
        - Characters
        - Voices
- On-line testing

LEARNING MANAGEMENT

How do you feel about your use of the Destination Math system?

- System navigation
    - Menu
    - Test, assignment and progress tracking
- Learning management
    - Responsibilities
    - Effectiveness: Using Destination Math to learn math

STUDENT EXPERIENCES WITH MATH TESTING

Could you tell me how you feel about the PSSA math test you have next week?

- Preparation for math tests
    - Saxon tests
    - Destination Math tests

- Strategies, activities

Conclusion: The student is asked to contribute any other responses to his or her use of Destination Math. He or she is invited to ask any questions. The student is thanked again for his or her willingness to be involved in this research.

Appendix I: Semi-Structured Student Interview II

The following interview guide will be used to conduct a second, individual, semi-structured interview with four eighth grade students. The interview occurs at the end of the research, and serves as a validation check of the research findings. This interview will be scheduled for approximately 25-35 minutes.

Introduction: The student is thanked in advance, for giving of his or her time for this interview. He or she is reminded that no one but the researcher will have access to the interview conversation. The researcher invites and answers any new questions about the research purpose, focus, or future directions.

INTEREST IN MATH AND PERCEPTIONS OF MATH RELEVANCE

Could you tell me what you think of math in school (regular math class with Saxon, and math class with Destination Math in the computer lab)?

- Life-relevance
- General use
- Experience

MATH UNDERSTANDING

How do you feel about the way you use Destination Math to learn math concepts in the computer lab?

- Access and use of four main entry points to DM
  - Tutorials
  - Workouts
  - Practice problems
  - Tests

MILIEU

What do you think about the environment or atmosphere in the lab when you're using Destination Math?

- Teacher's role
- Student's role
- Peer-teacher interaction

LEARNING CONTROL

Do you think you have many choices to manage your own learning in the lab?

How do you use these choices?

- How you learn
- What you learn

How do you decide what to do next when you have completed your test questions and prescribed assignments?

How do you move around the different activities?

- System navigation

Conclusion: The student is asked to contribute any other responses to his/her use of Destination Math. He/she is invited to ask any questions. The student is thanked again for his/her willingness to be involved in this research.

Appendix J: Student Focus Group Session I

The following interview guide will be used to conduct an exploratory focus group interview with eighth grade students in groups of approximately 4-8 students. This interview will be scheduled for approximately 25-35 minutes.

The following activities introduce the focus group interview:

1. Brief review of research: To learn about what students think about, and how they feel about the use of technologies (computer technologies, etc.) to learn.
2. Reminder of focus group activity (participant and moderator roles, time)
    a. Students' role:
       To share attitudes, feelings, beliefs, and experiences with regard to the questions or topics posed.
    b. Moderator's role:
       To ask questions
       To challenge students to think about the topic
       To promote debate
       To keep the conversation focused
       To ensure everyone has a chance to speak
       To listen (without judgment)
3. Reminder of confidentiality of participants contributions to meeting
4. Student questions or queries

EDUCATIONAL TECHNOLOGY AND LEARNING

Could you think about your entire secondary school experience, and tell me about all of the computer/technology toys and tools you have used to learn something?

Have you used any other computer tools anywhere else (home), which helped you learn?

EDUCATIONAL TECHNOLOGY AND MATH

Which of these resources have you used to learn about math?

- Math as topic
- Math as class

How have you used these computer tools?

- Tasks
- Tools
- Group structure

How do various computer tools help you to learn about math? or
What does the computer do to help you learn?

- Refer to specific tools
- Role of computer tool

EDUCATIONAL TECHNOLOGY DESIGN

Can you describe exactly what you like about computer tools that help you learn?

- Interface?
- Motivation? (What makes them interesting?)
- Workload? (Offload cognitive tasks?)

STUDENT EXPECTATIONS FOR THE EDUCATIONAL TECHNOLOGY INNOVATION

If RVDP hired you in the morning as an educational consultant to assist them in designing their new math software, what suggestions would you make to them?

What should a good interactive math system look like, sound like and do?

Conclusion: Students are asked to contribute any other responses to their use of educational technologies, expectations for the RVDP materials in their math class, or questions about the research. Students are thanked again for their willingness to be involved in this research.

Appendix K: Student Focus Group Session II

The following interview guide will be used to conduct a final focus group interview with eighth grade students in groups of approximately 4-8 students. The interview occurs at the end of the research as a validation check of the research findings. This interview will be scheduled for approximately 25-35 minutes.

The following activities introduce the focus group interview:

1. Brief review of research: To learn about what students think about, and how they feel about the use of technologies (computer technologies, etc.) to learn.
2. Reminder of focus group activity (participant and moderator roles, time)
    a. Students' role:
       To share attitudes, feelings, beliefs and experiences with regard to the questions and topics posed.
    b. Moderator's role:
       To ask questions
       To challenge students to think about the topic
       To promote debate
       To keep the conversation focused
       To ensure everyone has a chance to speak
       To listen (without judgment)
3. Reminder of confidentiality of participants' contributions to meeting
4. Student questions/queries

INTEREST IN MATH AND PERCEPTIONS OF MATH RELEVANCE

Could you tell me what you think of math in school (regular class with math text or computer lab with Destination Math program)?

- Life-relevance
- General use
- Experience

MATH UNDERSTANDING

How do you feel about the way you use Destination Math to learn math concepts in the computer lab?

- Access and use of four main entry points to DM
    - Tutorials
    - Workouts
    - Practice problems
    - Tests

MILIEU

What do you think about the environment or atmosphere in the lab when you're using Destination Math?

- Teacher's role
- Student's role
- Peer-Teacher Interaction

LEARNING CONTROL

Do you think you have many choices to manage your own learning in the lab?
What do you think about those choices?

- System Navigation
- Learning Management

Conclusion: The students are asked to contribute any other responses to their use of Destination Math. They are invited to ask any questions. Students are thanked again for their willingness to be involved in this research.

Appendix L: Student Informed Consent Form for Behavioral Research Study

The Pennsylvania State University

Project Title: Interactive Learning Systems: Student/Teacher Perceptions and Experiences

Research Investigator: Sarah FitzPatrick (Doctoral Student in the College of Education)

Please Note: *You may decline to answer specific questions.*

This is to certify that I ______________________________, have been given the following information about my participation in this research study.

1. **This study is** part of a research project designed to increase our understanding of students' experiences with educational technology in schools.

2. **If I agree to take part in this research, I will be asked to** talk about my use of educational technology in the classroom, in school and at home. I will also complete a short survey, and participate in interviews designed to find out how I feel about the use of technology for learning.

3. **My participation in this study will take approximately** 24 hours (approximately 2 hours per week for 12 weeks, beginning in Spring 2001), during the course of my regular math classes, and during the regular school day.

4. **This study will involve the use of** audio recordings, which will be used to record my discussions about the use of computers, and other learning resources in the math class.

I have been given the chance to ask any **questions I may have about the research** and these questions have been answered. I can discuss any other questions I may have, at any time, with the Assistant Superintendent of Tussey Mountain School District, Dr. Ronald D. McCahan, or with the research investigator, Sarah FitzPatrick, at:

The Pennsylvania State University
204A Hammond
University Park, PA 16802-1401

Phone: (814) 865-9300
Fax: (814) 863-7496
E-mail: sarahf@psu.edu

5. Only the researcher, Sarah FitzPatrick, will have **access** to the interview and classroom recordings and surveys that I may participate in.

6. I understand that **my participation is voluntary**. I can drop out of the study at any time.

8. **I will not experience any risks in this project.** This means that I will not experience any safety or health risks by participating in this project other than those risks I experience in a daily basis at school.

Participant:
This is to certify that I volunteer to participate in this research study.

- I have read and understood this form.
- I know that I can drop out of this study at any time.
- I know that I will be given a signed copy of this form.

____________________	___________________________	_______________
Name *(Use All Capital Letters)*	**Signature**	**Date**

Researcher:
I certify that the informed consent procedure has been followed, and that I have answered any questions from the participant, as fully as possible.

____________________	___________________________	_______________
Name *(Use All Capital Letters)*	**Signature**	**Date**

Appendix M: Parent/Guardian Informed Consent Form for Behavioral Research Study

The Pennsylvania State University

Project Title: Interactive Learning Systems: Student/Teacher Perceptions and Experiences

Research Investigator: Sarah FitzPatrick (Doctoral Student in the College of Education)

Please Note: *You may decline to answer specific questions.*

This is to certify that I ______________________, (on behalf of my minor child, _______ _____________________), have been given the following information with respect to my child's participation in this program of investigation under the supervision of Sarah FitzPatrick.

1. **The study in which my child will be participating is** part of a research project designed to understand students' experiences with educational technologies in school.

2. **If we agree to take part in this research, my child will be asked to** talk about and show how he/she uses educational technologies for math learning. He/she will also complete a survey, and may participate in interviews designed to find out how he/she *feels* about the use of technology for learning.
3. The Assistant Superintendent of Tussey Mountain School District, Dr. Ronald D. McCahn, supports this project.

4. **My child's participation in this study will take approximately** 24 hours (approximately 2 hours per week over a 12 week period, beginning in Spring 2001).

5. **This study will involve the use of** audio recordings, which will record your child's discussion about the use of computers, and other learning resources in the math class.

6. My child and I may ask any **questions about the research procedures,** and these questions will be answered. I can discuss any other questions I may have, at a any time, with the Assistant Superintendent of Tussey Mountain School District, Dr. Ronald D. McCahan, or with the research investigator, Sarah FitzPatrick, at:

The Pennsylvania State University
204A Hammond
University Park, PA 16802-1401

Phone: (814) 865-9300
Fax: (814) 863-7496
E-mail: sarahf@psu.edu

7. Only the researcher, Sarah FitzPatrick will have **access** to the interview and classroom recordings and surveys that my child may participate in.

8. I understand that **my child's participation is voluntary**. He/she is free to stop participating in the research at any time, without penalty.

9. **No known risks are associated with this project**. This means if my child participates in this project, he/she will not experience any safety or health risks other than those risks that he/she experiences on a daily basis at school.

Parent or Guardian for Participant:

I agree to my child's participation in this research exploration of how students experience and perceive educational technology in their math class.

- I understand the information given to me, and I have received answers to any questions I may have had about the research.
- I understand, and agree with the conditions of the study as it has been described.
- My child has no physical or mental illness or difficulties that would place him/her at risk, by participating in this study.
- I understand that my child's participation in this project will involve regular participation in math classes.
- I understand that my child's participation in this research is voluntary, and that he/she may withdraw from this study at any time by notifying Sarah FitzPatrick, the Research Investigator.
- I understand that I will receive a signed copy of this consent form

_________________	___________________________	________________
Name	**Signature**	**Date**
(Use All Capital Letters)		

Researcher:

I certify that the informed consent procedure has been followed, and that I have answered any questions from the participant and his/her parent/guardian above, as fully as possible.

_________________	___________________________	________________
Name	**Signature**	**Date**
(Use All Capital Letters)		

Appendix N: Categories and Subcategories of the Bloom et al. Taxonomy of Educational Objectives

Table 19

Categories and Subcategories of the Bloom et al. Taxonomy of Educational Objectives

Level	Categories[a]	Cognitive Activity
1[b]	*Knowledge* • Knowledge of Specifics • Knowledge of Ways and Means of Dealing with Specifics	Define, Enumerate, Identify, Label, List Match, Name, Read Reproduce, Restate
2[b]	*Comprehension* • Translation • Interpretation • Extrapolation	Classify, Cite, Convert, Describe, Discuss, Explain, Paraphrase, Summarize
3[c]	*Application* • Use of abstractions in particular and concrete situations	Apply, Choose, Demonstrate, Employ, Implement, Operate, Practice, Report, Teach, Transfer, Use, Write
4[c]	*Analysis* • Analysis of Elements • Analysis of Relationships • Analysis of Organized Principles	Analyze, Break down, Calculate, Correlate, Diagram, Differentiate, Discriminate, Distinguish, Illustrate, Outline
5[c]	*Synthesis* • Production of a Unique Communication • Production of a Planned or Proposed Set of Operations • Derivation of a Set of Abstract Relations	Arrange, Assemble, Compare, Contrast, Create, Design, Formulate, Integrate, Negotiate, Plan, Rearrange, Reconstruct, Reorganize, Substitute
6[c]	*Evaluation* • Judgments in Terms of Internal Evidence • Judgments in Terms of External Criteria	Appraise, Argue, Assess, Choose, Compare, Conclude, Critique, Defend, Estimate, Judge, Justify, Evaluate

[a](Bloom et al, 1956) [b]Higher Order Thinking Skills (HOTS) [c]Lower Order Thinking Skills (LOTS)

Appendix O: Levels of Taxonomic Analysis of Math Tasks

(A) Level 2: Comprehension

Essentials of Fractions, Workout 2, Question 4 In heavy traffic, the Jebra uses 1/8 of a gallon of gas every quarter of an hour. If the zebra is in traffic for 1 ¼ hours, how much gas will it use?		**Taxonomic Analysis**
Researcher:	So how are you doing, here, Tanya?	
Tanya:	I don't know, I don't know [pause]. One-eighth of a gallon of gas [pause] How much… [Tanya continues to read the question to herself.]	L1 (Repeat)
Researcher:	What are you looking for?	
Tanya:	It wants to know how much gas the Jebra uses for, in traffic for an hour [pause]. Well, or one and one fourth hours [pause].	L2 (Explain)
	And I know that, that it uses one-eight of a gallon of gas every one-fourth hour [pause].	L1 (Recall)
	But I don't know how to find [pause]. I just don't know. [Tanya moves the cursor toward the *Show Me* button, pauses, and clicks it.]	
DM:	In this question, you were asked to find how much gas the Jebra will use in one and one-fourths in traffic. One and one fourth, can be written as one, plus one fourth. Since there are four-fourths in one, you could also express one and one-fourth as four-fourths plus one fourth…	

(B) Level 3: Application

Decimals: Part 4, Test, Question 4 Picture of number line with the least and greatest numbers marked, .42 and .46, respectively. Justin has marked two numbers on this number line. What is the product of these two numbers? Express your answer as a decimal. Type in your answer.		**Taxonomic Analysis**
Researcher:	So what are you going to do with this one, Brian?	
Brian:	Multiply em.	L1 (Repeat)
Researcher:	Why?	
Brian:	Because it says, there [pause] product.	L2 (Convert)
	[Brian uses his calculator to find the answer.]	L3 (Employ)

(C) Level 4: Analysis

Decimals: Part 3, Test, Question 1 Evaluate 14.6 + 2.15 + 19.0 Express your answer as a decimal. Type in your answer.		**Taxonomic Analysis**
Researcher:	So Chris, if you could speak your thoughts aloud for this one-	
Chris	Ah-ha. Em. [Reading] Evaluate fourteen point six plus two point one five plus nineteen point zero.	L1 (Repeat)
	So I'll just add these up. [Chris speaks his mental computation aloud]. Eh, fourteen point six plus two point one five plus nineteen. So that's three point five point seven five. [Chris types in his answer.]	L4 (Calculate)

(D) Level 5: Synthesis

Integers: Part 2, Test, Question 4 -5 x 2 = -10, -5 x 1 =-5, and –5 x 0 = 0. Use this pattern to find –5 x –1. Type in your answer.		**Taxonomic Analysis**
Researcher:	So, Beth, what are you up to here?	
Beth:	Eh, I don't know[pause]. Find negative five times negative one [pause]. And there's a pattern here somewhere [pause].	L1 (Repeat)
	There's negative five there, all the way through it. And then the two changes to one and one changes to zero, in some of em [pause] and the answers are different, like ten and five and zero.	L4 (Discriminate)
	So it's [the answer] getting smaller by one, two [pause] I don't know [pause].	L4 (Calculate)
	Minus ten, then minus five and zero, so that's five [pause]. The numbers are getting smaller, no bigger [pause]. Eh. Would the next one be five?	L4 (Distinguish)
Researcher:	Why do you think that?	
Beth:	Because these are all changing in the same way?	L5 (Compare)
Researcher:	Good woman.	
	So I just enter five, right? [I nod, and Beth enters 5 as her answer.]	

(E) Level 6: Evaluation

Essentials of Fractions, Tutorial 3, Practice Area, Question 3 Which fractions are represented by this pair of circle graphs? Select your answer: 11/8 1 5/8 1 3/8 1 3/8		**Taxonomic Analysis**
Tanya:	Eh, which fractions are represented [continuing to read to herself].	L1 (Repeat)
	Oh. [Tanya moves the cursor over the shaded and unshaded portions, as if counting each fraction part.] Eh, one and one-third. I think this is right.	L4 (Calculate)
Researcher:	How did you figure that out?	
	Cause there's a whole thing shaded out, and then there's three eights of another one.	L2 (Explain)
Tanya:	Em, this one [first answer] might be right.	L5 (Compare)
Researcher:	How will you know if that's the answer?	
	Well, there is eleven, but I wasn't sure, since there's two [circles] if you had to add eight and eight. So this is right. So there is eleven shaded. I don't think anything else [pause] I don't think anything else works. [Tanya uses the calculator.]	L6 (Judge)
Researcher:	What are you doing there?	
Tanya:	I was just seeing what this is as em, a mixed number thing [pause]. But its only one and one eight [pause]. So I'll keep my answer [one and three eights].	L6 (Evaluate)

Appendix P: Taxonomic Analysis of Students' Levels of Cognitive Engagement with Destination Math Tasks

(A) Taxonomic analysis of students' levels of cognitive engagement while working on DM test questions

Figure 10 shows that for over 50% of the test problems analyzed (n=156) students were engaged in the most complex and abstract level of cognitive activity, represented by Level 6 on Bloom's Taxonomy. Thirty-two percent of the remaining problems were completed by students who demonstrated analysis and synthesis of mathematical concepts, represented by Levels 3 and 4. Only 6% of test questions analyzed showed that students attained no higher than Level 2 (lower order thinking skills [LOTS]) on DM test questions. Ninety-four percent of DM test questions engaged students in higher order thinking skills (HOTS), represented by Levels 4 to 6.

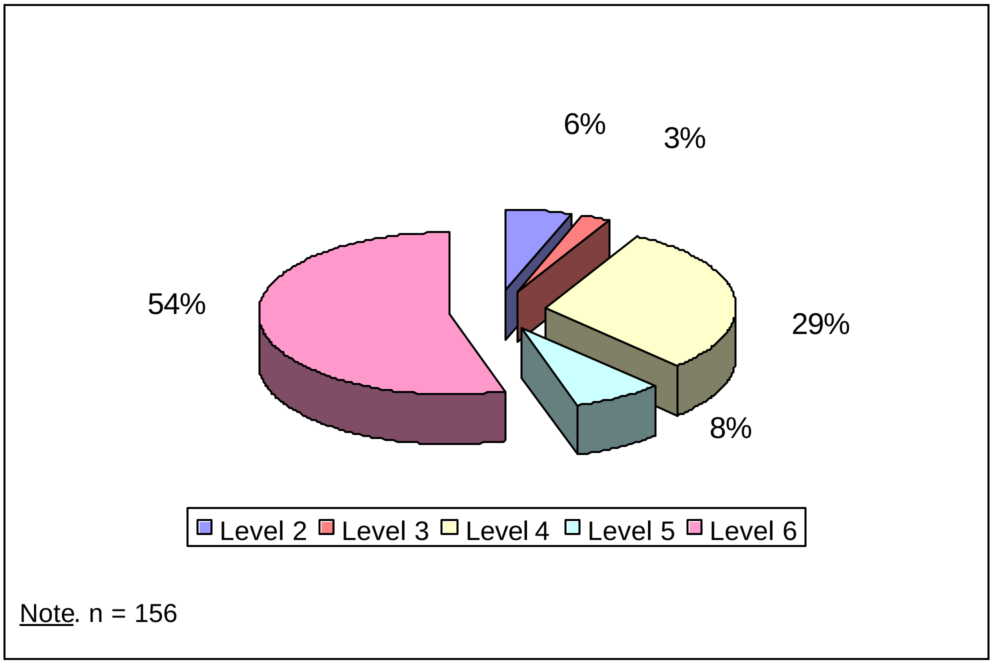
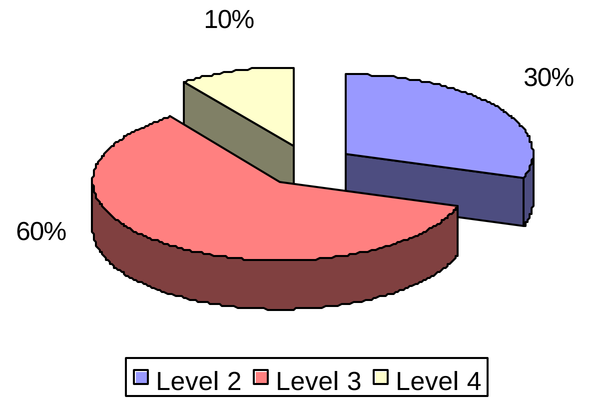


Figure 10. Taxonomic Analysis: DM Test Questions

(B) Taxonomic analysis of students' levels of cognitive engagement while working on DM tutorials

Figure 11 presents the analysis of 10 student-completed DM tutorials (n=10). For the 10 math problems analyzed, students demonstrated comprehension (Level 2) of math concepts for 30% of problems, application (Level 3) of math concepts for 60% of problems, and analysis (Level 4) of math concepts for 10% of problems. Thirty percent of tutorial problems analyzed engaged students in LOTS, while the remaining 70% of problems engaged students in HOTS. This analysis reflects the dual purpose of DM tutorials in providing scaffolds for student recall and rehearsal of math concepts, and the application of concepts to novel problems.

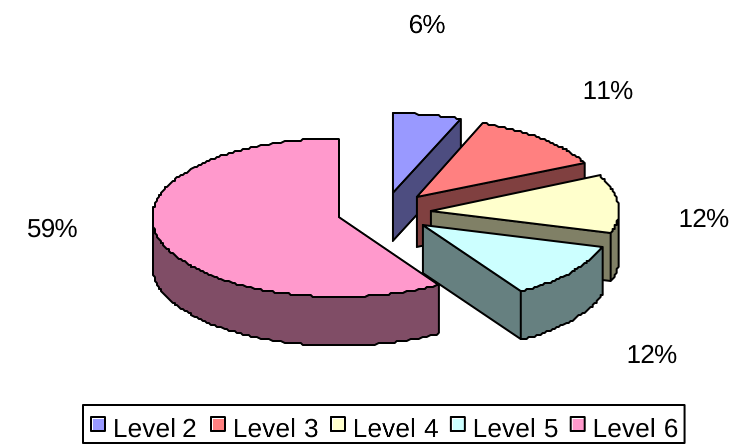


Note. n = 10

Figure 11. Taxonomic Analysis: DM Tutorials

(C) Taxonomic analysis of students' levels of cognitive engagement while working on DM practice problems

Figure 12 presents my analysis of 17 student-completed DM practice problems (n=17). Figure 12 shows that of the 17 problems analyzed, 59% of these engaged students in the highest level of cognitive activity, evaluation. Six percent of the problems analyzed indicated Level 2 (as the highest level of) student cognitive activity. The remaining problems were equally distributed across Levels 3 (application), 4 (analysis) and 5 (synthesis). Ninety-four percent of practice problems analyzed engaged students in HOTS. Figure 3 suggests that the DM practice problems provide opportunities for students to extend their engagement with math concepts beyond the practice and preliminary applications of math concepts provided in DM tutorials.



Note. n = 17

Figure 12. Taxonomic Analysis: DM Practice Problems

(D) Taxonomic analysis of students' levels of cognitive engagement while working on DM workouts

Figure 13 presents my taxonomic analysis of 17 student-completed DM workout problems (n=17). The distribution of completed student workout problems across cognitive activity Levels 2-6 is similar to the distribution discussed in Figure 12, for DM practice problems. Figure 13 shows that 53% of problems analyzed engaged students in the highest level of cognitive activity, evaluation. Levels 4 and 5 were the highest levels of cognitive activity demonstrated by students for 24% of problems analyzed. Seventeen percent of students demonstrated application of math concepts learned (Level 3) as the highest level of cognitive activity. Only 6% of problems analyzed indicated Level 2 (as the highest level of) student cognitive activity. Figure 13 shows that, similar to the analysis of student practice problems, students demonstrated HOTS for 94% of workouts analyzed.

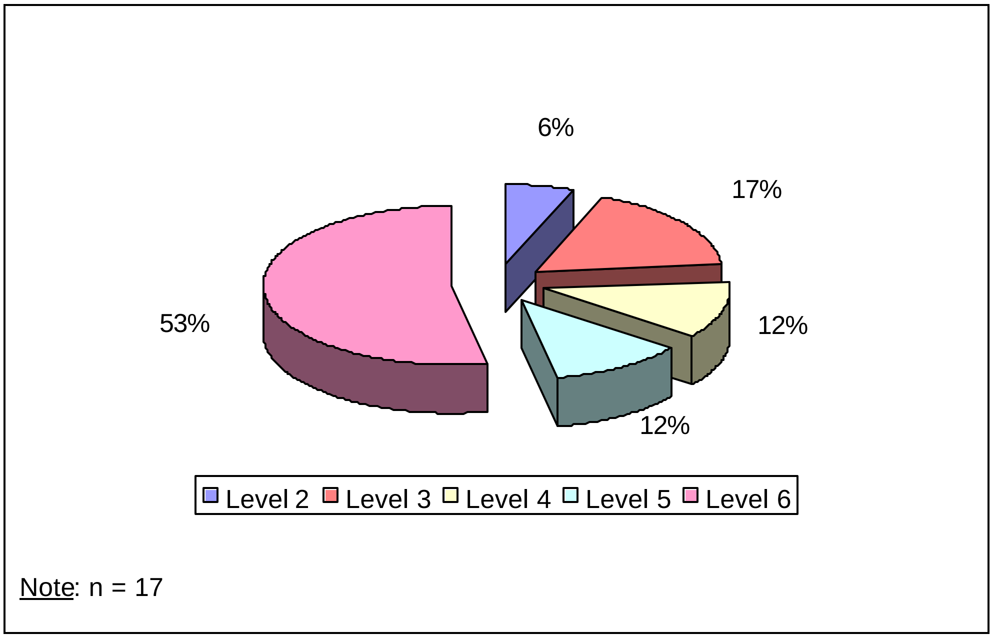


Figure 13. Taxonomic Analysis: DM Workouts

Appendix Q: Raw Data: Analysis of Students' Cognitive Engagement with Destination Math

Table 20

Analysis of Students' Cognitive Engagement with DM

	Test	**Practice**	**Tutorial**	**Workout**
Level 1	0	0	0	0
Level 2	9	1	3	1
Level 3	4	2	6	3
Level 4	47	2	1	2
Level 5	12	2	0	2
Level 6	87	10	0	9
n =	159	17	10	17

Appendix R: Raw Data: Analysis of Students' Time-on-Task with Destination Math

Table 21

Analysis of Students' Time-On-Task with DM[a]

Date	Log	Time-on-Task	Time-off-Task
2/212001	1	11	0
2/22/2001	1	11	0
2/282001	1	9	2
3/1/2001	1	10	1
3/1/2001	2	10	1
3/2/2001	1	10	1
3/6/2001	1	11	0
3/21/2001	1	11	0
3/21/2001	2	10	1
3/22/2001	1	10	1
3/22/2001	2	10	1
3/28/2001	1	10	1
3/29/2001	1	10	1
3/29/2001	2	11	0
4/4/2001	1	11	0
4/4/2001	2	11	0
4/5/2001	1	10	1
4/18/2001	1	11	0
4/18/2001	2	11	0
4/19/2001	1	11	0
4/25/2001	1	11	0

Note. [a](n=11)

VITA

Sarah B. FitzPatrick

1998-2001	The Pennsylvania State University (PSU) University Park, PA, USA	Ph.D. *Instructional Systems*
2000-2001	Instructional Designer Women in Engineering Program (WEP) College of Engineering, PSU	
1999-2000	Instructional Designer Engineering Instructional Services (EIS) College of Engineering, PSU	
1998-1999	Supervisor of Pre-Service Student Teachers Office of Pre-Service Student Teaching Experiences (OPTE) College of Education, PSU	
1997-1998	Middle School Language Arts Teacher Annunciation Catholic Academy Altamonte Springs, FL, USA	
1995-1997	Lecturer in Education Mary Immaculate College (MIC) University of Limerick Limerick, Ireland	
1994-1995	Frostburg State University (FSU) Frostburg, MD, USA	M.Ed. *Curriculum & Instruction*
1994-1995	Supervisor of Pre-Service Student Teachers Microteaching Lab Department of Educational Professions College of Education, FSU	
1992-1994	Primary (Elementary) School Teacher Scoil Barra (St. Finbarr's Primary School) Ballincollig, Co. Cork, Ireland	
1989-1992	MIC, National University of Ireland (NUI) Limerick, Ireland	B.Ed. *Primary School Education*