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Abstract

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Teachers' responses to questions in a flowing conversation were searched for common themes, and excerpts of those conversations were placed in a table to facilitate the analysis of the concepts and ideas the teachers were trying to convey. The common themes that teachers talked about were: the limited time in a teacher's day; implementing effective change in a classroom setting is a process that can take years; administrative support is secondary but important; professional development is critical and should be ongoing; technology in teaching and learning in the content area is essential; classroom practice improves because of technology implementation; and the innovative technology features used in the classroom depend on the content taught.

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TEACHERS' PERSPECTIVES ABOUT IMPLEMENTING A CONTENT-SPECIFIC
TECHNOLOGY INNOVATION

A Dissertation
Presented to
the Morgridge College of Education
University of Denver

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

by
Thomas Stovall Hibbs

August 2010

Advisors: Linda Brookhart, Ph.D. and Kent Seidel, Ph.D.

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This research was designed to examine the implementation of a technology innovation in a content area from teachers' point of view. Three classroom teachers who were involved in organized implementations of a technology innovation at the school level were asked to describe their implementations. They then were asked to review those implementations through four specific lenses that research indicates are important: school change, factors affecting implementation of technology innovations, technology in their content area, and examining their use of developers' innovative improvements. Finally the classroom teachers were asked, as a summary technique, to talk about factors important to include in a written implementation plan.

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I want to sincerely thank the teachers who took the time to participate in these interviews and give their perspectives on analyzing and planning implementations of technology innovations.

Many times we forget in our journey through life that we are not alone. In my case, my mother and father provided an example of the importance of education in a person's life, as well as the responsibility to continue striving both for personal growth and to help improve the lives of others. My mother and father graduated during the depression of the 1930's. They were outstanding in their professions of school librarian in Nelson County, Kentucky and director of officer instruction training at Fort Knox, Kentucky. During the process of taking classes and preparing this dissertation, my mother died after spending a couple of years in a nursing home. It was only during this time that I realized how important she was in my life; how important her challenge to me has been all my life. It was their personal integrity and their concern for others including our family that has kept me trying to improve myself and be more able to advocate for others.

My wife Sallie and I have done everything together for the last forty years. This project is no exception.

Finally, after my mother's death, I would not have completed this thesis work and dissertation without the encouragement and help of my Ph.D. advisor, Dr. Kent Seidel, and my dissertation advisor, Dr. Linda Brookhart. I want to recognize how special their help and support was in finishing what I had started years earlier.

Table of Contents

Chapter One: Introduction	1
Background.....	1
Definitions.....	2
Research Question	10
Change and Technology	11
Implementing Change in Schools	12
Successful Implementation of Technology Innovations.....	13
Technology Impacts Teaching and Learning in the Content Area	14
Technology in the classroom is consistent with national standards.	15
Summary	17
Chapter Two: Review of Literature	18
Rate of Change of Technology	18
Change Theory and Schools	20
Factors that Affect an Implementation of a Technology Innovation.....	24
Technology in the Content Area.....	27
Teacher knowledge and beliefs about technology, content, and teaching.....	27
Student choice and content area tasks.....	28
Student knowledge and use of new technology skills.	28
Mathematical gains by students using technology.....	29
Research supporting technology use in the classroom.	30
Description of the Technology Innovation, Possible Uses, and Impacts.....	33
Chapter Three: Methodology	38
Background and Study Design	38
Interviewee Selection and Population Information.....	40
Data Collection	42
Analysis of Data.....	44
Limitations	46
Chapter Four: Analysis of Results	47
Meeting the Teachers.....	48
Teacher One.....	48
Teacher Two.....	48
Teacher Three.....	49
Interviews.....	49
Teacher One’s experience.....	50
Teacher Two’s experience.....	52
Teacher Three’s experience.....	54
Determining a Level of Use.....	55
Finding Common Themes.....	55

Time in a teacher’s day for implementation is limited.	56
Implementation is a process that can take years.	58
Administrative support is secondary but important.	60
Professional development is critical and should be ongoing.	60
Technology in teaching and learning is essential.	64
Classroom practice improves because of technology implementation.	66
Technology features used depend on the content taught.	68
Summary Question from the Interviews	70
Key Implementation Factors.....	70
Chapter Five: Discussion	74
Classroom Teachers Looking Through the School Improvement Lens	75
Classroom Teachers Looking Through the School Improvement Lens	76
Classroom Teachers Looking at Implementing a Technology Innovation.....	78
Classroom Teachers Looking at Technology in the Content Area.....	80
Classroom Teachers Looking at Their Functional Use of the Innovative Technology	81
The Foci from the Teacher’s Reflections.....	82
Scheduling and Time.	82
Professional Development and Teacher Commitment.	83
Equitable Student Access and Family Engagement.....	84
Collegial Support.	85
Recommendations for Further Research.....	86
Researcher’s Conclusion.....	87
References.....	91
Appendix A: Expected Uses of the TI-Nspire	95
Appendix B: Informed Consent Form	97
Appendix C: Interview Guide.....	99
Appendix D: Interview Summary Form	102
Appendix E: Data Analysis Organizer.....	103

Chapter One: Introduction

Background

Technology has changed our world and continually changes our lives; a few relatively recent examples include the Internet, cell phones, iPods, Blackberries, computerized cars, high definition television, electronic game devices, and home appliances. Not only does technology continue to change our lives dramatically, but the rate of change has dramatically increased. In 2009, AirTran made WiFi available to passengers on all its flights. On an airline flight it is common to sit next to a child who is surfing the web. Julie Evans, President and CEO of Project Tomorrow, is quoted in the Business to Education News Alert (2009) as saying

It is widely accepted by students that arrival at school means “powering down” for a few hours. After leaving school, they resume their technology-infused lives and leverage a wide range of emerging technologies to fine tune their skills in communicating, collaborating, creating and contributing in ways that are never approached during the school day. (p. 1)

Project Tomorrow was the sponsor of Speak Up 2008, which polled more than 270,000 students from all fifty states about their views and uses of technology.

Technology is changing our access to and exchange of information, as well as our methods of person-to-person and person-to-masses communication. The technological tools with which we interpret and use that information are also changing. Advances in technology also have a fundamental impact on teaching and learning in a classroom setting. This study examined the implementation of a technology change by schools in Colorado from the lens of the teachers participating in the implementation projects focusing on the teachers’ perceptions of the implementation after the first year and their perception of the factors that affected that implementation.

Learning to teach with technology is not optional today; it is mandatory. Therefore, learning to effectively implement technology into our education systems, and especially our classrooms, is not optional either. This study describes three such implementations and will illuminate and analyze the actual experiences of the teachers involved, so that other school administrators and teachers can improve their decision making, planning, implementation, and use of technology innovations.

Definitions

The terms below are used throughout this study.

Classroom response system. Combination hardware and dedicated software system using a teacher's computer and devices in student hands that communicate feedback to teachers, feedback that teachers can display for all students to see. Generally the feedback from the students to the teacher is in the form of responses to multiple choice questions, but some more specialized systems allow students to respond to the teacher with open-ended responses, fill in the blank responses, and show screens on the student devices, such as a graphing calculator screen.

Connect to Class™. Combination of hardware and software that allows a teacher to simultaneously download content files from the teacher's computer to multiple (maximum of 8) TI-Nspire™ handheld units.

Graphing calculator. An electronic handheld device that is widely used in algebra classes, and functions as a scientific calculator as well as graphs functions electronically. Prior to the graphing calculator, students had to construct a table

of values and draw graphs by hand, plotting the values on a pair of axes most commonly for values of x and y .

Handheld device. In this particular reference a handheld is a device that can be held in one hand and manipulated by the other. Common handhelds are graphing calculators, TI-Nspires, and scientific calculators. They differ from a laptop (computer) that is also portable, but is usually supported on a desk or table and is manipulated with both hands.

Implementation. For this study, implementation is referred to as the entire process from the decision to adopt an innovation or change to the level of use that Hall and Hord (2006) describe as the renewal level. The level at which the users evaluate the technology; find improved or new uses; seek modifications or alternatives to improve impact on students.

Interactive white board. The interactive white board is a combination of a computer, white surface similar to a white board in a classroom, software, and marking devices. The marking devices are used at the board and detected by the system to drive the mouse on a computer. Modern interactive white boards include computer programs that allow content to be displayed and then saved for future reference. They are sometimes referred to as smart boards, although that is actually a particular manufacturer's trade name.

Investigation. A mathematics problem which defines a situation and requires students to solve one or more mathematical problems to investigate the concept or arrive at a complex solution. Investigations are generally thought of as more involved than a

simple problem to solve with a numerical answer. In many investigations the student must choose a method of solution or use multiple methods of solution.

Level of Use. In this paper, level of use refers to a specific continuum set up by Hall and Hord (2006) to evaluate school change. The continuum is described starting on page 18. The level of use generally refers to the permanence of change in a school setting.

Millennium Generation. A generation loosely defined as children who grew up using computers and surfing the Internet. Schools had access to the modern Internet from approximately 1994 after the introduction of Netscape™.

National Council of Teachers of Mathematics (NCTM). The largest and most influential mathematics teacher organization for kindergarten through grade twelve.

Portable Document Format Files. (PDF) One of the most common form of files found on the World Wide Web. The files have minimized size for easier transmission and a free Adobe Reader™ can be downloaded from the Internet to enable reading these files.

Professional Learning Community (PLC). A group of professionals (in this study usually teachers) who meet regularly to help each other learn new information and skills.

Sketchpad™ (more formally named Geometer's Sketchpad™). An interactive geometry program produced by Key Curriculum Press and popular in math classes since the early 1990's.

TI-84Plus™. A graphing calculator produced by Texas Instruments and commonly used in algebra classes and classes depending on algebra as a prerequisite. The TI-84Plus™ has a predecessor, the TI-83Plus™ that is generally the same, but less memory and speed of calculation.

TI-Nspire™. Sometimes referred to as the Nspire is a handheld computer for mathematics and science produced by Texas Instruments. It is a newer generation of the graphing calculators after the TI-84Plus™. It stores files and has more applications than just calculating and graphing, such as interactive graphing, interactive statistics and data displays, and a spreadsheet.

Study Purpose and Rationale

This study was an investigation of the implementation of the same math technology innovation at three different high schools. A review of literature and research provides four different lenses to relate to technology implementation:

1. School change theory: describes the level of use of an innovation and was devised by Hall and Hord (2002). This lens poses the question of what factors contributed to or diminished one's level of use.
2. Successful integration of a technology innovation: Which factors contributing to the success of a technology innovation were important in reaching the level of use described above? Research focused on implementing technology is much more specific to the problems of technology than changing the climate or culture of an educational organization.

3. Improving teaching and learning of mathematics: How has teaching and learning of mathematics changed as a result of using this innovation?
4. Meeting developer's functional expectations: using and operating the technology and integration of the usage into the classroom.

This study lets the teacher evaluate his/her implementation and communicate what factors influenced him/her to achieve their level of use. Teacher responses were analyzed through all the lenses listed above and also allowed the teacher to determine new themes. The conclusions drawn from listening to the teachers provided important insights to administrators or other teachers who are embarking on a journey to implement new, significant technology into the classroom.

Participants in this study came from various Colorado school districts. In 2006 and 2007, several school districts and individual schools in Colorado were committed to improving the use of technology in teaching mathematics in order to enhance effective teaching and improve student learning. The districts and schools began to actively explore new math technologies that they viewed as an improvement over old technology used in the districts and schools. A new handheld mathematical computing device, the TI-Nspire™, would provide a more effective technology tool for students than the more limited handheld graphing calculator.

One of the districts developed a formal implementation plan that was to introduce the technology to teachers first, thus stimulating a desire for change. All math teachers in that district were given the option to attend an introductory workshop in the summer of 2008 and receive a classroom set of the devices at the beginning of school for the 2009-

2010 school year. The entire mathematics department at one school in that district decided to adopt this technology. Some of those teachers followed the district option and the district paid for the classroom technology and the cost of the professional development. There were no mandates on usage in a teacher's classroom, e.g., teachers were free to determine when and how they would use the technology in their own classrooms. Some of those teachers learned more about the device and suggestions for integrating it into their curriculum by participating in additional professional development workshops. One teacher from one of the high schools participating in this district project became part of this study.

The second district in this study began their planning in 2008, but also distributed the new technology to schools at the beginning of the 2009-2010 school year. The number of classrooms allowed in this project depended on the particular school and how much previous support had been given to the school. The school in this study was limited to two classrooms that were included in the implementation. One teacher from that school participated in this study.

The third school in this study was not part of a district plan, but a school plan. The math department in that school decided to adopt this new technology using a process similar to the first district where the decisions to adopt and implement were reached after attending some introductory workshops. In this case all of the teachers in the mathematics department were subsequently invited to attend the 3-day training workshop. One teacher from that school participated in this study.

The device used in this study, called TI-Nspire™, operates like a limited-function computer. As such, the innovation was major and not like a change in operating systems or a new version of software that includes a few changes. The new handheld replaced a number of existing math technologies: the graphing calculator, spreadsheets found in general computer software, specialized interactive geometry, statistics and data analysis software for computers, and data collection using scientific probes (SRI International, 2006). Each teacher was supplied with emulator software to demonstrate usage and prepare content, so teacher usage and student usage were not automatically the same. Each classroom set included a set of USB hubs and an associated program, Connect-to-Class™ which enabled student handhelds to be connected to the teacher's computer for uploading and downloading teacher-originated files and files from the Internet. Because the TI-Nspire™ represents a dramatic change in both function as a device and the mathematics it to which it relates, and since Texas Instruments graphing calculators have dominated the K-12 handheld market and are the calculators of choice in most high schools, it is a good technology innovation to use to identify how teachers view an implementation of new technology and their perception of how teaching and learning are affected by using this innovation.

Several lenses exist for analyzing the value of this technology innovation for teaching mathematics. Each lens has its own research base and is typically dealt with separately; but to thoroughly examine the implementation of a content-specific technology innovation all four lenses are important. One view is through change theory in schools. Another view includes factors that contribute to the implementation of a

technology innovation. Since this innovation is focused on mathematics teachers, a third aspect is the impact of a new technology on teaching and learning of mathematics. Finally, technology is generally expensive and adoption of new technology comes with expectations for new or improved functionality provided by the specific hardware or software. Thus, a fourth view is from looking at the specific technology itself and asking if the functional use of the new technology meets the expectations that enabled its acquisition. Zhao, Pugh, Sheldon, & Byers (2002) note that for an innovation to have a significant impact on student learning, it must be used. It is with that orientation that this study examines teachers' perceptions of their implementation of this innovation in their mathematics classrooms.

This study is a phenomenology, a qualitative research design that “identifies the ‘essence’ of human experiences concerning a phenomenon as described by participants in a study” (Cresswell, 2003, p.15). During this study, teachers implementing a technology innovation in their mathematics classroom described their level of use of the technology and described the factors they feel were responsible for that level of use. Giving teachers the voice to communicate what they perceive as critical factors affecting their use of a new technology will allow teachers and administrators involved in an implementation to successfully lead and manage implementations of content-specific technology innovations in schools and districts. Teachers will be given the challenge of examining this implementation from all four view points and identify factors they feel influenced the success, or lack of success, of their implementation.

Research Question

This study was a description of a content-specific technology innovation implementation in one school through the perception of teachers. The research question was:

What were the classroom teachers' perceptions of their level of use after the adoption of a technology innovation and what factors influenced them to achieve that level of use?

The study identified the factors that influenced teachers' implementation of a content-specific technology innovation. As a mathematics teacher with experience teaching with specific math technology from the early 1970's through 2000, then as the state coordinator of a math technology project – MathStar - that was initiated by the Los Angeles County Office of Education and included the Monterey County Office of Education, the New Mexico Department of Education and New Mexico State University, and the Colorado Department of Education and Adams State College and Otero Junior College, and finally as a technology consultant for Texas Instruments, I was in an excellent position to listen to the voices of teachers involved in this study and discover the factors they feel are important for implementing a technology innovation in a content area. I had read and relied on the quantitative research but now have asked teachers who participated in a content-specific technology implementation to tell their story and lead us along their path providing a link between their experience and current research and literature.

Teacher responses were analyzed through four lenses suggested by current research: school change theory, implementation specifically of a technology innovation, technology in the content area, and specific technology uses and impacts. The analysis opened the gateway (Mears, 2009) for teachers through their responses to create new themes not suggested by current research. This research, to a large extent reflecting the voice of the teachers, contributes important and necessary aid to educators in adopting technology innovations that improve their teaching and their students' learning.

Change and Technology

The next two sections establish the importance of mastering change in technology and why technology is important in the mathematics classroom for pedagogical reasons and to modernize the content of the curriculum. In schools, technology can help transform yesterday's classroom to one that is exciting to the Millennium Generation. As noted in Ray Kurzweil's (2001) "The Law of Accelerating Returns,"

An analysis of the history of technology shows that technological change is exponential, contrary to the common-sense "intuitive linear" view. So we won't experience 100 years of progress in the 21st century—it will be more like 20,000 years of progress (at today's rate). The "returns," such as chip speed and cost-effectiveness, also increase exponentially. There's even exponential growth in the rate of exponential growth. Within a few decades, machine intelligence will surpass human intelligence, leading to The Singularity—technological change so rapid and profound it represents a rupture in the fabric of human history. The implications include the merger of biological and non-biological intelligence, immortal software-based humans, and ultra-high levels of intelligence that expand outward in the universe at the speed of light. (para. 1)

Accelerating change is due to an increase in the rate of technological progress throughout history, which suggests even faster, more profound changes in the future.

Educational leaders must make rapid decisions about how to implement technological changes and support teachers in adopting such changes. Again, Kurzweil (2001) notes,

The paradigm shift rate (i.e., the overall rate of technical progress) is currently doubling (approximately) every decade; that is, paradigm shift times are halving every decade (and the rate of acceleration is itself growing exponentially). So, the technological progress in the twenty-first century will be equivalent to what would require (in the linear view) on the order of 200 centuries. In contrast, the twentieth century saw only about 25 years of progress (again at today's rate of progress) since we have been speeding up to current rates. So the twenty-first century will see almost a thousand times greater technological change than its predecessor. (para. 6)

Implementing Change in Schools

The evaluation of an adoption of a technology innovation and implementation into classroom practice demands an understanding of implementation of change in schools. Hall and Hord (2006) have developed Twelve Principles of Change in an effort to help schools understand and implement change. This section primarily deals with changing classroom climate and culture. The twelve principles are

1. Change is a process, not an event.
2. There are significant differences in what is entailed in development and implementation of an innovation.
3. An organization does not change until the individuals within it change.
4. Innovations come in different sizes
5. Interventions are the actions and events that are key to the success of the change process.
6. There will be no change in outcomes until new practices are implemented.
7. Administrator leadership is essential to long-term change success.
8. Mandates can work.
9. The school is the primary unit for change.
10. Facilitating change is a team effort.
11. Appropriate interventions reduce resistance to change.
12. The context of the school influences the process of change. (pp 4-14)

Zhao et al. (2002) notes that for an innovation to have impact on student learning, it must be used. Along with Hall and Hord's Twelve Principles of Change, they have

devised a description of Levels of Use to address the question of how fully an innovation is implemented. Innovation participants are separated into two classes as nonusers and users. Nonusers are sub-classified as Nonuse, Orientation, and Preparation. Users are sub-classified as Mechanical Use, Routine, Refinement, Integration, and Renewal. The term Levels of Use' pertains to "behaviors and portrays how people are acting with respect to a specified change". (Hall & Hord, p. 159)

Successful Implementation of Technology Innovations

Zhao et al. (2002) studied conditions that specifically influence whether a technology innovation can be effectively used in classrooms to improve student learning. This study followed a group of K-12 teachers who were given grants to fund technology-rich projects in their classrooms. The study identified eleven factors that significantly impact the degree of success of a classroom technology innovation. The eleven factors fit into one of three domains: the innovator, the innovation, and the context of the project. Three factors were associated with the innovator: technology proficiency, pedagogical compatibility, and social awareness. Innovations vary along two dimensions: distance and dependence. Distance refers to how far the innovation leads teachers from their status quo and dependence refers to how much help and from whom they need help to successfully implement their project. Three aspects of school context were identified: human infrastructure, technical infrastructure, and social support. This study will use these categories to help teachers in this project to identify factors important to their implementation.

Technology Impacts Teaching and Learning in the Content Area

As technology changes quickly in schools, school leaders need to be able to rapidly assess which of those changes are impacting classrooms and how the technological changes are making that impact. This investigation focuses on mathematics classrooms, so the types of technology that are important and degree of importance of the technology focuses on research and organizations important to the mathematics classroom. Those changes not only affect how the student learns, but what the student learns.

Technology and the pedagogical changes resulting from it (technology in mathematics education) have a decisive impact on what is included in the mathematics curriculum. In particular, what students are taught and how they learn are significantly influenced by the technological forces. (Ellington, 2003, p. 433)

The type and extent of gains in student learning of mathematics with handheld graphing technology are a function, not simply of the presence of handheld graphing technology, but of how the technology is used in the teaching of mathematics. Given supporting conditions, the evidence indicates that handheld graphing technology can be an important factor in helping students develop a better understanding of mathematical concepts, score higher on performance measures, and raise the level of their problem solving skills. (Burrill, Allison, Breaux, Kastberg, & Sanchez, 2002, p. i)

Burrill et al. (2002) found that most students use handheld calculators as a computational tool, to move among different representational forms, and as a visualizing tool (p. iv).

Results of a study involving Algebra 1 students using a curriculum that included specific uses of graphing calculators showed:

The more access students had to graphing calculators and the more instructional time in which graphing calculators were used, the higher the test scores. In addition, scores were significantly higher where teachers reported receiving professional development on how to use a graphing calculator in math instruction. (Heller, Curtis, Jaffe, & Verboncoeur, 2005, p. 2)

Technology in the classroom is consistent with national standards.

For the mathematics classroom, the National Council of Teachers of Mathematics (NCTM) has been a leading proponent of national standards. The NCTM is the most influential organization for K-12 math teachers and their recommendations guide K-12 math classrooms throughout the United States. The NCTM sets these goals for math teachers by issuing content and process standards. NCTM's latest framework for school mathematics teaching and learning begins with a vision of a modern classroom:

Imagine a classroom, a school, or a school district where all students have access to high-quality, engaging mathematics instruction. There are ambitious expectations for all, with accommodation for those who need it. Knowledgeable teachers have adequate resources to support their work and are continually growing as professionals. The curriculum is mathematically rich, offering students opportunities to learn important mathematical concepts and procedures with understanding. Technology is an essential component of the environment. Students confidently engage in complex mathematical tasks chosen carefully by teachers. They draw on knowledge from a wide variety of mathematical topics, sometimes approaching the same problems from different mathematical perspectives or representing the mathematics in different ways until they find methods that enable them to make progress. Teachers help students make, refine, and explore conjectures on the basis of evidence and use a variety of reasoning and proof techniques to confirm or disprove those conjectures. Students are flexible and resourceful problem solvers. Alone or in groups and with access to technology, they work productively and reflectively, with the skilled guidance of their teachers. Orally and in writing, students communicate their ideas and results effectively. They value mathematics and engage actively in learning it. (National Council of Teachers of Mathematics (NCTM), 2000, p. 3)

Technology in the mathematics classroom is still emerging today. Many districts provide each teacher with a computer and projector. Interactive white boards are common (Kollie, 2008). Classroom response systems collect responses and help teachers and students immediately evaluate student replies and store the student responses. A few schools have become "laptop schools," providing each student with a laptop (Berlinger,

2001). In math classrooms, graphing calculators have been prevalent for years. The first graphing calculator was introduced by Casio in 1986 as the FX7000G™ (Waits, 1994). The first Texas Instruments graphing calculator, the TI-81™, was released in 1988. The Report of 2000 National Survey of Science and Mathematics Education stated that more than 80% of high school mathematics teachers completing the survey used handheld graphing technology in their classrooms (Weiss 2001). In 2005, a new classroom system (the TI-Navigator™) was released to connect graphing calculators to the teacher's computer and project group inputs, and collect, check, and display student responses to both formative and summative assessments. The system can also display the screens of students' calculators to make learning truly an interactive group effort. A number of math programs have been developed for computers. Interactive geometry, spreadsheet, data representation, and data analysis programs are widely used in secondary school classrooms. Some math classrooms, but primarily math modeling projects, use purchased and/or student-generated computer programs for simulations. Math classes consistently using technology are very popular with students and teachers see a higher level of student interaction (NCTM, 2000).

The NCTM bases its standards for school mathematics on six principles: equity, curriculum, teaching, learning, assessment, and technology. The Technology Principle states, "Technology is essential in teaching and learning mathematics, it influences the mathematics that is taught and enhances students' learning" (NCTM, 2000, p. 24). The National Research Council states, "Instruction that makes productive use of computer and

calculator technology has beneficial effects on understanding and learning algebraic representation...” (Swafford & Findell, 2001, p. 420)

Summary

Technology is changing our world and our schools. Our students are currently part of the technology-driven world. Since technology advances are moving exponentially faster, school districts need to be better able to cope with technology changes and implementation of new technology-based innovations. Research into change in schools and specifically to implementation of technology innovations in schools have been addressed from each of these frameworks. Especially in mathematics teaching and learning, there has been a substantial amount of investigation about the effects of teaching and learning using technology. There is also research that identifies expectations for specific uses of new technology.

This study adds a new dimension to the study of implementation of content-specific technology innovation into the classroom. The teachers’ perception of their levels of implementation and the factors influencing those degrees of implementation will provide important information for more effective development of plans for implementing innovations involving technology. This study was a description and analysis of the teachers’ perceptions of the implementation of a new technology in the mathematics classroom.

Chapter Two: Review of Literature

This chapter presents literature regarding rapidity of change of technology, how change impacts schools, factors shown to be associated with successful implementation of technology innovations in schools, technology used in teaching mathematics, research supporting the improvement of student learning associated with the use of technology, and finally a description of the new technology in this project and research showing what can be expected from its use.

Rate of Change of Technology

The rapid changes taking place in the use of technology in our lives is sometimes brushed off with a statement like “change happens.” Understanding more about these changes illuminates the importance of being able to effectively introduce and implement change in our schools. The wheel was invented around 3500 BC in Mesopotamia (“Wheel,” n.d.). The wheel remains an important device in most machines today. When the American Revolutionary War was fought, we were still pulling wagons with horses, and letters delivered by hand was the method of long-distance communication. Engines were connected to wheels first on the railroads in about 1825 (“Railroad,” n.d.). It wasn’t until 1837 that patents were issued for the telegraph (“Telegraph,” n.d.). From the invention of the wheel, it took about 5000 years to be able to move from place to place on land without a horse or walking, and to be able to directly communicate beyond one’s sight with another human. Then in the next 175 years came the automobile, the airplane, the rocket, space travel, electricity (now supplied by batteries, water, coal, atomic power, solar power, wind power), and the computer.

In just 50 years, the computer went from an accounting machine to the platform for surfing a world-wide communications system. Computer chips are in most sophisticated devices that require monitoring and controls. Calculators started with the abacus about 1100 BC (“Abacus,” n.d.), then the slide rule based on Napier’s invention of logarithms was introduced by William Oughtred in 1632, approximately 2700 years later (“Slide Rule,” n.d.). The pocket calculator was invented by Jack Kilby of Texas Instruments in 1967 (“Pocket Calculator,” n.d.), just 335 years after the slide rule. The graphing calculator, an advance, but not a whole new device, was first marketed in 1987. The latest handheld device, the TI-Nspire™, is more like a math computer than the first series of electronic calculators. Introduced in 2006, the TI-Nspire™ software program is also available for use on the handheld or can be installed on a computer. The Navigator™ system that wirelessly connects the handhelds to the teacher’s computer was

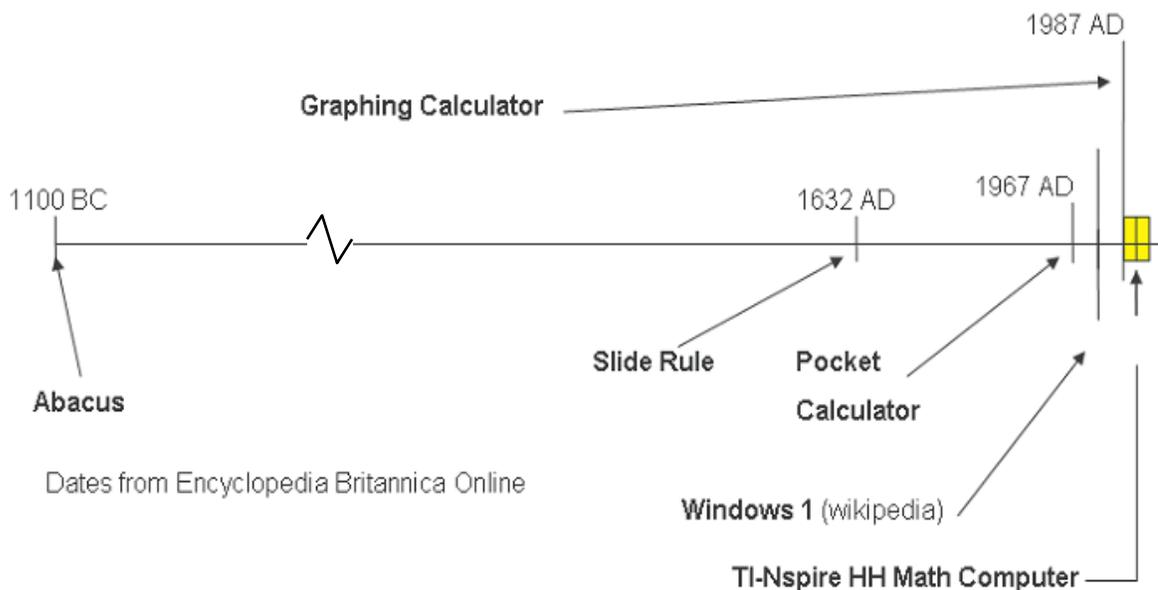


Figure 1. Time line for handheld computing devices.

first available in December 2009. The time line (*Figure 1*) illustrates the advances in handheld computing. It is not drawn to scale.

The rapid change in technology is due to the exponentially increasing capacity of computer chips. As noted in Ray Kurzweil's (2001) "The Law of Accelerating Returns,"

An analysis of the history of technology shows that technological change is exponential, contrary to the common-sense "intuitive linear" view. So we won't experience 100 years of progress in the 21st century—it will be more like 20,000 years of progress (at today's rate). The "returns," such as chip speed and cost-effectiveness, also increase exponentially. There's even exponential growth in the rate of exponential growth. Within a few decades, machine intelligence will surpass human intelligence, leading to The Singularity—technological change so rapid and profound it represents a rupture in the fabric of human history. The implications include the merger of biological and nonbiological intelligence, immortal software-based humans, and ultra-high levels of intelligence that expand outward in the universe at the speed of light. (para. 1)

We can expect to see more online resources and expanded connections between technologies. As an example, Texas Instruments has program downloads, academic content, classroom materials, professional development, and interactive lessons, as well as commercial information on its web site <http://education.ti.com>.

Change Theory and Schools

In an effort to help schools understand and implement change, Hall and Hord (2006) have developed "Twelve Principles of Change". Their twelve principles are

1. Change is a process, not an event.
2. There are significant differences in what is entailed in development and implementation of an innovation.
3. An organization does not change until the individuals within it change.
4. Innovations come in different sizes
5. Interventions are the actions and events that are key to the success of the change process.
6. There will be no change in outcomes until new practices are implemented.
7. Administrator leadership is essential to long-term change success.

8. Mandates can work.
9. The school is the primary unit for change.
10. Facilitating change is a team effort.
11. Appropriate interventions reduce resistance to change.
12. The context of the school influences the process of change. (pp 4-14)

Planning and subsequent implementation of a change are two separate stages in the process. The task of ensuring each classroom, and therefore each student, has access to the best technology tools for their improved learning and, ultimately, improved achievement is a daunting task. There are overall goals for technology such as using multiple resources of information, promoting interactive learning, improving student engagement, enabling improved concept building and visualization, supporting more comprehensive problem solving, enhancing effective collaboration, improving formative assessment, and making classroom administration more efficient. Some technologies are universally adaptable, such as an Internet-connected computer with office software, a classroom projector, document reader, interactive white boards and classroom management software. Within a discipline, certain technologies are more important than others, such as probeware in science, graphing calculators in math, and global positioning system (GPS) devices in geography. The number of teachers involved in an innovation will help determine the resources needed for the implementation and whether the trainer will be local or a specialist from the outside. Generally, specialists from each academic discipline will need to lead, or at least be on the leadership team, for discipline-based technology to integrate the usage into the curriculum.

The plan should be for each teacher adopting the innovation to become a high level user in which they not only concentrate on ease and skill of use, but use that is the

highest level of value to the student. The evaluation of success in an implementation can be guided by Hall and Hord's (2006) concept of Levels of Use. Innovation participants are separated into two classes as nonusers and users. Nonusers are sub-classified as Nonuse, Orientation, and Preparation. In most instances, an organization adopting an innovation will move through these stages in the early stages of either investigation or early adoption. The orientation might be a stage in the decision-making process. Are teachers ready and willing to take on the project? Do teachers buy into the concept? After the district or school decides to add a new technology, they prepare the teacher to adopt the innovation. One of the principles of change is that each individual must change or adapt before the organization has genuinely made the transition. The preparation might be introduction and orientation to the technology, purchase and installation, and initial training in using the innovation. This is all the first stage of adopting the innovation. For a technology innovation, this stage can be (and normally is) handled by leaders in the district or the school. Many times, this is where those leaders and the vendor declare victory.

Users are further subdivided into five other levels. The initial level of use is mechanical. The instructional technology department or the academic coaches assist teachers with the mechanical, day-to-day use of the innovation. Depending on the complexity of the innovation and the readiness of the user, this may be easy or may be a long process. A technology innovation might have several layers of use. As an example, the innovation this study will examine is an extension of hand-held graphing calculators which have been in general use in the mathematics classroom since the late 1890's. With

this much use before the new device was introduced in 2006, there should only be a moderate learning curve. However, the handheld calculator is joined by three software applications which were generally found in a well-equipped math computer lab. Many teachers have never used these applications or only on special assignments when taking the class to a computer lab. The handheld is like a computer. Both teachers and students can create, download, and upload content files. Accompanying software has been designed for the teacher as the classroom management software allows them to quiz students and instantly check the responses, making formative assessment manageable and more effective. If a teacher were using all these facets of the innovation, the trainers might think their task is accomplished; however it is just a beginning.

The second level of use is making the use routine. At this level, the technology is used without much preparation, without much extra thought, and without much improvement. With all the focal points in today's administrative and teaching jobs, this level is worthy of a victory celebration. The advanced user levels of refinement, integration, and renewal are actually the goals of an innovation with legs to remain a part of the instructional system. At the refinement level, the user begins to vary the use in order to have a better impact on the students. It is no secret that classes change from year to year and even period to period. At the refinement level, variations are sought that have both short-term and long-term effects.

The next level of use, integration, visualizes the teacher collaborating with colleagues to combine their refinement level activities to achieve a group improvement and common sphere of influence. It is only at this level that the department, the school,

or the district has actually adopted the innovation. At this level the innovation will outlast the next teacher or principal resignation. Finally, Hall and Hord (2006) theorize the renewal level, i.e. the level at which the users evaluate the technology, find improved or new uses, and seek modifications or alternatives to improve impact on students. The complete adoption of an innovation is well beyond the routine mechanical use.

Factors that Affect an Implementation of a Technology Innovation

Schools that are able to effectively and efficiently implement change are going to be in stronger positions in the future as the rate of change increases and technology innovations are even more central to student learning. Zhao et al. (2002) from Michigan State University completed a study of the conditions that affect classroom technology innovations. In that study, they felt a fundamental issue around the interaction between technology and education is the conditions under which the use of classroom technology can affect student learning. They were able to isolate eleven salient factors that affect the adoption of a technology innovation that successfully affects student learning. These eleven factors fit into three domains: the innovator, the innovation, and the context of the implementation (Zhao et al, 2002).

The three factors Zhao et al. (2002) associated with the innovator are technology proficiency, the degree to which the technology is compatible with the innovator's pedagogical beliefs, and the knowledge of organizational and social culture of the school. A teacher's technology proficiency not only refers to the ability to operate the piece of equipment, but also the enabling conditions for using that technology (Zhao et al., 2002, p. 491). Although using technology in the mathematics classroom is generally accepted

(NCTM, 2000), teachers individual beliefs are varied (Burrill et al., 2002, p. 15). The final factor that was associated with a successful technology innovator in the classroom was the teacher's ability to interact with the school organization and culture (Zhao et al., 2002, p. 494).

The second domain is the innovation itself. Some innovations are easier to implement. The ease of implementation varies along two dimensions, distance and dependence. Distance refers to how far the teachers and students must go to implement the innovation -- how distant the innovation is from the culture of the school, from current classroom practices, and from available technology resources (Zhao et. al., 2002). A familiar example is the "back to basics" debate about the use of technology. Levine (1999), when discussing a school that prides itself on a traditional approach to teaching, posits "... the school ranks in the 96th percentile nationally. What makes it effective? It's rooted in the basics: traditional education, hard work and values. The administrators pride themselves on not being cutting edge." Implementing a technology innovation is that school might be very unwanted by the rest of the staff, the administration, parents, and activists in the community.

The distance from current classroom practices is illustrated by examples from math classrooms. In a math classroom that is covering basic factoring, a teacher might use abstract letters like x and y and whole numbers. $4x + 4y = 4(x+y)$ is typically presented without using technology. Solving an equation that is not set up to have whole numbers like one that might be from physics ($32t^2 - 5.5t + 17.25 = 5$), can be approached from several different directions, but using technology enables multiple representations

and multiple methods of visualization. Plane geometry has in the past depended largely on a compass, straight edge, ruler, and protractor to make and analyze figures. If modern interactive geometry software is introduced into that traditional classroom, the teacher not only has to learn how to operate the program, but when to use the technology and when to use the physical tools. The most successful projects were the ones that were variations of an existing practice and thus not too distant from current classroom practices (Zhao et al., 2002, p. 498).

The opportunity to fully implement a technology innovation also depends on the current state of technology in the classroom, the school, and the district (Zhao et al., 2002).

Dependence refers to reliance on other people, either within or beyond the innovator's immediate control. Projects that required little cooperation, participation, or support from others not under the control of the innovator were the most successful. Technology innovations can also require the use of technological resources beyond the control of the innovator. The most successful projects tended to depend on the least technology out of the control of the innovator (Zhao et al., 2002, p. 501).

The third domain of context includes the human infrastructure, the technological infrastructure, and social support. A good human infrastructure in a school would include a helpful technology staff, a person or group of people who could help the teacher understand and use the technologies, and an administration that would support the teacher's project. The presence of a "translator" who helps the teacher understand and use the technology for her own classroom needs was most important even when the

innovator did not experience problems (Zhao et al., 2002, p. 503). There must be adequate technological infrastructure to implement the innovation. Finally, the innovator needs social support.

Technology in the Content Area

This section of the review establishes the importance and relevance of technology to teaching mathematics, the content area that is the focus of this study. The designer of the implementation needs a thorough background of how previous technology has affected the content area instruction and student learning and how the new technology might change that teaching and learning. This would be one of the reasons a content-area specialist would be part of the planning and implementation teams. A 2002 synthesis of literature on “Handheld Graphing Technology in Secondary Mathematics: Research Findings and Implementations for Classroom Practice” was conducted through a grant to Michigan State University. The report concentrates on five central questions, which will serve as subheadings for this section (Burrill et al., p. 10).

Teacher knowledge and beliefs about technology, content, and teaching.

There is a positive relationship between teachers’ overall beliefs about mathematics and their beliefs about handheld graphing technology. Rule-based and non-rule-based teachers perceive student use of handheld graphing technology differently, with the former noticing affective aspects of students’ reactions and perceiving the technology as an enhancement to instruction, and the latter focusing on the cognitive or conceptual aspects of students’ reactions and perceiving graphing calculators as integral to instruction. A rule-based teacher is likely to primarily teach a procedure such as

factoring and then show some applications such as word problems. A non-rule-based teacher is likely to concentrate on problem solving and introduce procedures as they are needed in problem solutions. Teachers' use of handheld graphing technology differed widely, but instead of changing teacher practice, teachers tended to continue to teach as they had when handheld graphing technology was introduced into their classrooms. The review found that teachers' knowledge, beliefs, and personal philosophies influenced how they used graphing calculators in their classrooms. (Burrill et al, p. 14-15)

Student choice and content area tasks.

The findings in this section of the report describe students' choices of solution strategy, and how students used the technology to carry out these tasks. Most of the usage studied involved graphing.

...there were no studies in those reviewed that examined how students used handheld technology associated with plane geometry or statistical tasks and only one study that investigated trigonometry. The research primarily focused on function and coordinate graphing, and not on the use of the technology to perform simulations, make statistical plots, manipulate data, work with inequalities, or collect and analyze data. (Burrill et al., p. 28)

The studies were about upper-level mathematics; few studies looked at middle-grades students. In talking about the implications for classrooms regarding calculator use, Burrill et al. (2002) believe teachers must teach the students how to use the technology, as well as the limits of the technology, and must design appropriate tasks with the technology in mind (pp. 20-29).

Student knowledge and use of new technology skills.

There were 23 research reports relevant to the questions "What mathematical knowledge and skills are learned by students who use handheld graphing technology?"

and “In what ways do students use this knowledge and these skills?” The research topics included functions, algebra, pre-calculus, and calculus. Burrill et al. (2002) found that students learn what they are taught either implicitly or explicitly with regard to graphing calculators. Access also makes a difference. The types of problems students spent the most time learning were the problems the students performed better on during testing. The outcomes reinforced the idea that student learning of mathematics with a graphing calculator is not a function of the technology alone. The factors that the review of research by Burrill et al. (2002) suggests are significant are length of time with access to the technology, student–teacher interaction, how the tool is used, and the existing mathematical knowledge and beliefs of the student (p. 35). One of the gaps in the review is that no study investigated the potential of handheld graphing technology and what it is possible to learn with this technology.

The nature of the curriculum and the assumptions made about the role of handheld graphing technology in the curriculum are important. With or without graphing technology, there seem to be parts of the curriculum on which students do poorly. Students in both experimental and control groups did not do well on multiple representations of algebraic ideas and on understanding function as an entity rather than a process, suggesting that teachers might need to rethink how they approach these ideas. Because students using handheld graphing calculator technology learn to solve problems using multiple methods, teachers should be prepared to help students examine those methods to see when they generalize or what assumptions or limitations might be inherent in a particular method. (Burrill et al., 2002, p. 36)

Mathematical gains by students using technology

To investigate the questions “What is gained mathematically by students using handheld technology that cannot be observed in a non-technology environment?” and “In what ways do students use this knowledge and these skills?”, eleven studies compared

students who used handheld graphing technology to those who did not. The findings indicate the use of handheld technology had a positive impact on student performance. The topics examined were conceptual understanding of function, solution strategies, linking representations and understanding attributes of functions, performance on a comprehensive final exam, and use of a symbolic calculator on procedural problems that were deemed calculator-friendly. Students with access to handheld graphing technology outperformed those without access on multi-step problems, problems involving applications, and those using real data. Again, a gap in the studies that could be reviewed shows a very narrow segment of mathematics addressed. There were no studies on statistics or discrete mathematics, or development of reasoning and proof (Burrill et al., 2002, pp. 38-46).

Research supporting technology use in the classroom.

This study focuses on the use of technology in the mathematics classroom. There are several meta-analyses that indicate that graphing calculators have a positive impact on student achievement and change classroom practice. Establishing that graphing calculators have a positive impact on student achievement establishes the relevance of further research concerning different facets of their use and impact in the classroom. Since this study concerns the capabilities of a particular handheld device (TI-Nspire™), and since that handheld greatly increases the scope of mathematics impacted, previous research on the use of graphing calculators in the classroom will be briefly analyzed to determine what skills, content, and classroom practices were addressed.

A study by Khoju, Jaciw, and Miller (2005) titled “Effectiveness of Graphing Calculators in K–12 Mathematics Achievement, a Systematic Review” used the No Child Left Behind (NCLB) What Works Clearinghouse criteria. The criteria were that the study should be relevant, should provide strong evidence of causal validity, should be conducted in a K–12 setting, reference to education should be current (since 1985), and the study should be based on research that is accessible (U.S. Department of Education, 2003). The study found a .85 effect, showing a strong indication that the use of graphing calculators is associated with better performance in algebra (Khoju et al., 2005, p. ii). Selected by Khoju et al. to be analyzed were studies by Drottar (1998), Hollar and Norwood (1999), Graham and Thomas (2000), and Thompson and Senk (2001).

According to Khoju et al., the Graham and Thomas study published in 2000 was motivated by earlier findings (Tall and Thomas, 1991) about the improvement of algebra performance for students using computer activities. In the words of Khoju et al., Graham and Thomas viewed the graphing calculator as a portable and affordable alternative to the computer (Khoju et al., 2005, p. 5).

The Drottar study used concepts from Algebra II. The Hollar and Norwood study dealt with the concept and application of functions. The skills included modeling a real-world situation, interpreting a function, different representations of functions, and transitioning from the operational to the structural phase of using functions. The Graham and Thomas study tested student understanding of the use of letters as specific unknowns, generalized numbers, and variables in elementary algebra. The Thompson and Senk

study published in 2001 dealt with four chapters of second-year algebra (Khoju et al., 2005, p. i).

Joan Heller and colleagues (Heller et al., 2005) investigated the use of graphing calculators to impact student achievement in Algebra 1. There are several findings of the Heller et al. study that might apply to the present study. In their study, more graphing calculator access and more graphing calculator use during Algebra 1 courses resulted in higher end-of-course test scores taken without a calculator. Further, scores were significantly higher for students in classes where graphing calculators were used on topics less frequently taught by the other classes in the study including the topics of linear inequalities, nonfunctions, and quadratic equations. With respect to teacher training, students did significantly better in classes with teachers who participated in trainings on how to use the graphing calculator and better in classes with teachers who participated in training using other computerized graphing technology. Students did significantly worse in classes with teachers who self-taught themselves on graphing calculators with the manual. Heller et al. suggest that using a test that does not use graphing calculators to eliminate that bias might understate students' knowledge by eliminating questions that can only be reasonably answered on a timed test with graphing calculator use (Heller, pp. 20-21).

In summary, published studies on graphing calculators concentrated on algebra topics. (Burrill et al, 2002; Ellington, 2003; Heller et al., 2005; Khoju et al., 2005) The studies showed significant positive effect on student learning when students are using graphing calculators. (Ellington, 2003; Heller et al., 2005; Khoju et al., 2005) This study

addresses change that results from the introduction of a new technology in the mathematics classroom. One important change from the past use of graphing calculators would be teachers' use of the new technology in mathematics classes other than algebra and courses which directly depend on algebra.

Description of the Technology Innovation, Possible Uses, and Impacts

This section describes the characteristics and capabilities of the TI-Nspire™ handheld, which is the technology innovation upon which this study is focused. In the United States, Texas Instruments commands an overwhelming portion of the graphing calculator market for K-12 schools. Thus this technology will seem to emphasize Texas Instruments, but simply reflects the dominance of that company in the K-12 handheld market in the county being studied. If the innovation being studied were electronic science probes, the study might have related almost exclusively to Vernier products. Several years ago, a study of interactive geometry software in the United States would have been about Key Curriculum Press' Geometer's SketchPad™ as it was the overwhelmingly dominant product. The K-12 math or science markets are so small and specialized, that there have been dominant products. It takes a product such as the computer projector before the market is large enough to attract several manufacturers that have significant shares of the market.

Before the introduction of the TI-Nspire™ handheld, the graphing calculator was the dominant technology in the mathematics classroom and had been since its introduction in the late 1980's. The numerical graphing calculators primarily deal with graphical representations of functions, scientific calculations, multiple representations,

lists of data, and one- or two-variable statistics from lists. The differences between the TI-81™ graphing calculator introduced late in the 1980s and the TI-84Plus™, the current top end of the Texas Instruments numerical graphing calculators for general mathematics series, are mostly technical or pedagogical. The TI-83Plus™ added a flash memory, and preprogrammed applications that can be downloaded from a computer. The TI-84Plus™ has a faster operating system and larger memory. However, the lower screen resolution and the navigation keys on all of these models limit use of the interactive applications such as interactive geometry provided by Texas Instruments (SRI International, 2006). Texas Instruments maintains thousands of files containing classroom materials that teachers and developers have submitted. These files are available to the public in Texas Instruments' Activity Center on the main educational web site. It was not until the introduction of the TI-Nspire™ in 2007 that substantial changes were made that may affect the basic function of math handheld technology and its use in the math classroom.

One radical change is that the TI-Nspire™ opens files like a computer document, saves them in its memory, can transfer them to an associated computer program and, using the associated computer program, can print the file. These files may be developed by a teacher or other author on the associated TI-Nspire™ computer program. The files can be sent to the whole class using Connect to Class™ software or to several students at a time through USB hubs and cables. Students can open the files and edit them, complete the assignment, and then send them back to the teacher at a specified time. The teacher can reopen the file, now associated with the student through the Connect to Class™ software, check the work, and redistribute the files with only that student's file going

back to the individual student's handheld. All these functions open possibilities for use that the graphing calculator does not have.

The file looks like a PowerPoint™ presentation. The file is separated into problems that are single or multiple pages with mathematical variables defined for that problem. If a variable has another definition or reference, then another “problem” is started. Another primary change is the number of mathematical applications available. The pages function as applications: a calculator, graphing program, an interactive geometry program, a list or spreadsheet program, a data display and statistics program, data collection and storage program, or notes and text application. The screen resolution makes graphics, including graphs, geometry figures, and data plots much more legible than the graphics of earlier models. To improve viewing multiple representations, the page can be split and multiple applications viewed on a single page. The controls include a “Nav Pad™,” which controls the cursor much like a touchpad or a navigation stick on a laptop computer. The cursor is capable of grabbing graphs, text, and geometric figures. Variables, such as the radius of a circle, are user defined for each problem, and the variable can be used on any other page in that problem. The possibilities for multiple representations within a problem and exploring multiple methods of solving problems have increased radically. In short, the TI-Nspire™ is a handheld math computer.

The TI-Nspire™ is available as a handheld which is the version being introduced at the study's subject school. It is also available as student software on a PC or Macintosh™ computer. Software is available for teachers that includes an emulator of

the handheld, the same functionality as the handheld, and the ability to make assessments to be distributed to classes and then collected electronically and checked by the software.

The TI-Nspire™ is so different from other math handhelds that initially Texas Instruments only wanted the TI-Nspire™ to be distributed to teachers who had received training on the device. The manufacturer provided one-day introductions to thousands of teachers and three-day workshops that enabled teachers to begin use in class in 2007 and 2008, and conducted several shorter workshops to create awareness of the features of the device. All teachers involved in this study attended a three-day training to ensure they are ready to begin use when the school year started. Other professional development and support resources include TI-Nspire™ Cliffs Notes, an online course, organized user groups, and a daily telephone help desk.

SRI International's Center for Technology in Learning prepared a document for Texas Instruments documenting what educators can do with the TI-Nspire™ (SRI International, 2006). SRI International suggests a research basis of three layers: effectiveness, enhanced representation and communication of important mathematics, and deeper opportunities to learn. The expected and possible observable classroom practices will be organized under several general categories, including these three:

Effectiveness.

TI-Nspire™ builds on and unites two strong research findings: Graphing calculators enhance student learning and incorporating formative assessment into everyday teaching practice is highly effective.

Enhanced representation and communication of important mathematics.

TI-Nspire's™ linked representations should help teachers to focus students' attention on the relationships among multiple representations, such as

algebraic equations, geometric constructions, graphs, and tables. Networking capabilities can increase student participation and engage student in mathematical thinking and communication around these representations. TI-Nspire's™ multiple representation and communication capabilities can make thinking visible and can support the classroom teacher to engage students in doing and discussing important mathematics.

Deeper opportunities to learn.

Using the new document features of TI-Nspire™, teachers can develop classroom practices that increase the time students spend doing mathematics in an environment that has the ingredient for success: increased support for mastering difficult concepts and skills; high student participation; and tools for reflective practice. (SRI International, 2006, p.1)

The uses that might be found in a high school math class are numerous and can be found in Appendix A. Teachers' functional use is compared to this list and the factors which enabled or diminished that use are discussed in chapter 5.

Chapter Three: Methodology

Background and Study Design

This was a phenomenological study; it was a description of the implementation of an important technology innovation in one school through the perception of teachers. The study examined teachers' perception of their level of use of new technology and their perception of the factors involved in the implementations that are associated with that level. The study used responsive interviewing (Rubin & Rubin, 2005) to connect classroom teachers' perceptions of the implementation of content-specific to several frameworks established in the research literature and discover if they have other common themes which have not been investigated.

This study utilized in-depth interviews to elucidate the perceptions of teachers involved in the implementation of an innovative content-specific technological tool. This study was conducted within school districts having a planned implementation of the TI-Nspire™ handheld computing device in the mathematics classroom. The content research and literature cited are specific to mathematics. The expected and possible functional uses of the technology are specific to the TI-Nspire™. If the technology was a new word processing program in a composition classroom, the content research and literature would be different, but still necessary to that study; and the expected and possible functional uses would be different, but again necessary to know before the study.

Phenomenological research uses the responses of the participants in the study to capture the essence of their experience. (Creswell, 2003) The purpose of this study was to give teachers a voice in analyzing the implementation of the innovation and determining factors that administrators managing an implementation of a content-specific

technology innovation should consider. Creswell (2003) gives direction to the researcher. The focus should be on one phenomenon (p. 89); in this case, the implementation of a content-specific technology innovation of a single technology innovation at different schools. A phenomenology employs an emerging design and uses open-ended questions “enhanced by nondirectional language rather than predetermined outcomes” (p. 89). The design encourages participants to make meaning of their experience.

The in-depth interview was well suited to this project. The attributes for the study which match those of Mead (2009) for using an in-depth interview method include looking for an inside perspective that gives meaning to an experience for the purpose of developing a deeper understanding of that experience and informing program design and wanting to hear the authentic voices of those involved (p 76). During the interviews and the analysis, the researcher used the narrator check (Mead, 2009) to give narrators a chance to confirm the accuracy of the what the researcher heard, assess the meaning the researcher gave to their portrayals and the interpretation of meanings, and to reflect on added understandings that came through the research. The narrator check is a method of sharing with the narrator the excerpts and the use of the excerpts to make meaning and connections with other narrators and research concepts. The narrator check was used after each interview and during the final interview to insure the researcher correctly conveyed the meaning the narrator intended. The narrator check also allows the narrator the opportunity to work with the researcher to reword or remove any excerpt that her/she does not want to be public.

The innovation project involved the adoption and implementation by the mathematics department at several high schools in Colorado of the TI-Nspire™ handheld to replace the TI-84Plus™ graphing calculators, or similar graphing calculators, as the primary classroom technology. The expected outcome was an in-depth understanding of the implementation of a content-specific technology innovation from classroom teachers who were participants.

Research Question

The research question addressed in this study was:

What were the classroom teachers' perceptions of their level of use after the adoption of a technology innovation and what factors influenced them to achieve that level of use?

Interviewee Selection and Population Information

Ruben and Ruben (2005) suggest that “interviewees should be experienced and knowledgeable in the area you are interviewing about” (p. 64). Credibility is improved with choosing interviewees with a variety of perspectives. The interviewer should choose participants who will most likely know answers and provide relevant responses to the questions (p. 11). Three teacher volunteers were interviewed; teachers were selected by a convenience sample from a solicitation using a statewide mailing list of mathematics teachers in Colorado. The selection of the teachers was guided by the following criteria:

- (1) Various levels of implementation;
- (2) Variation of math teaching experience; and
- (3) Variation in the use of technology in their teaching.

The study was done using teachers from three Colorado high schools which implemented a planned math technology innovation in their mathematics department. The schools have approximate student populations from 1400 to 1800 students. In two of the cases, the school district had planned and facilitated the implementation of the innovative technology (the TI-Nspire™) and in the third case the math department of a school planned and facilitated the implementation. Participation by individual teachers in the district project was conditioned on three requirements: (1) Attendance at a three-day training, which was classroom-application oriented and provided by the manufacturer; (2) teachers were required to use the technology in math; and (3) teachers has some participation in a learning community within the school to share problems and best practices. All teachers on a state-wide mailing list were given the option of participating. Regional activities which were available to all Colorado teachers before deciding to participate in adoptions in their district were

- May 12, 2007 – 2 hour presentation on TI-Nspire™ during an all-day Math Technology Workshop in a Denver suburban school district in Colorado;
- October 27, 2007 – morning workshop introducing TI-Nspire™ in a Denver suburban school district in Colorado;
- March 1, 2008 – all day “Nspiration” Tour by Texas Instruments on TI-Nspire™ in a Denver suburban school district in Colorado;
- Summer Workshops, July 2008 -- 1.5 day and 3 day workshops on TI-Nspire™ funded by each district;

- May 3, 2008 – all day workshop including TI-Nspire™ strands in a Denver suburban school district in Colorado;
- November 15, 2008 – all day presentation on TI-Nspire™ including sessions in statistics, calculus, algebra, and geometry
- Summer Workshops, August 2009 -- 3 day workshop on TI-Nspire™ including sessions in advanced algebra content

Data Collection

The study consisted of three in-depth interviews with each of three participants in the content-specific technology implementations.

First Interview.

As Seidman (1991) suggests, “I interview because I am interested in other people’s stories. Most simply put, stories are a way of knowing” (p. 1). Each participant told his/her story about the implementation of a content-specific technology innovation and the factors they perceived as important during three one-hour interviews. Seidman suggests a series of three interviews, with the first to put the participant’s experience in context as it relates to the research question (p. 11). The goal of the first interview was to have the teachers relate their experience with this innovation. In their first interview, the participants were led with verbs that suggested open-ended responses so they had the opportunity to build their own understanding of the factors that were relevant in their implementation. The interviews (Appendix C) began with a simple prompt: In 2008 your department decided to adopt the TI-Nspire™ as a math technology to replace the

graphing calculator. You participated in that implementation of TI-Nspire™ in your classes. Tell me your story as it relates to that particular innovation.

Those responses were reviewed in order to identify excerpts which represented significant and focused thoughts important to the study. The researcher then discovered common threads between the participants, analyzed links to current research, and looked for themes which were not identified in the research and literature. The research gives us four different lenses to relate to narrators' stories which are elaborated under the topic of analysis.

Second Interview.

In the second interview the narrator was able to use the method of narrator check to view the excerpts of their narration, and then each was then asked to relate their experience to the themes found in the research. During this second interview, the leading questions for each participant were tailored to that participant's description of their implementation from the first interview. The interview generally, followed the outline given in Appendix C: Interview Guide. During the second interview, participants were shown a brief summary of the levels of use concept of Hall and Hord (2006), then participants were asked to specifically identify a level that applied to them. The teacher responded to questions about school change and implementing a technology innovation. The classroom teacher narrator became not just a story teller, but a partner in making sense of the experience.

Between the second and third interview, the interview transcripts were analyzed, segments excerpted, and the researcher made conclusions based on the narrations. The

third interview finalized developing links to related research discussed in chapter 5. In the second interview not all teachers reflected on all topics. This was due to each teacher being asked to elaborate on the links to the research specific to their description to their implementation.

Third Interview.

Therefore in the third interview, (Appendix C) the Interview Guide was followed closely asking all teachers generally the same questions. The teacher related their experience to technology in the content area and their functional use of the new technology. In addition through several summary questions, the classroom teachers reflected on making meaning of their experience (Seidman, 1991, p. 14). The last use of the third interview was to have the classroom teacher/narrators reflect on the conclusions reached, add their final meaning to the conclusions, and apply a narrator check to the final process ensuring they agreed that the conclusions were consistent with their intended meaning. The third interview gave interviewees a final chance to work with the researcher to reword or eliminate any material they felt should not included in the report.

Analysis of Data

The recorded interviews were transcribed and analyzed to discover common patterns and themes. One method of analyzing the transcripts was to perform a word search for instances and context throughout the transcripts. The unusual nature of the approach is that it may be used by any researcher looking for common themes with word processing documents or PDF files from the Internet without needing specialized

software. Word search provided by Adobe Acrobat Professional™ allowed the researcher to use words or phrases to discover, count, and review instances of the words or phrases in the transcripts of the teachers interviewed. The Word™ documents can be combined as Acrobat PDF™ files and made into a binder so the files remain separate parts of a larger document. The binder can then be searched for a word and every instance of the word along with an excerpt of the sentence around it is shown. This enables the researcher to find relevant incidences of the word by disregarding incidences with an alternate meaning of the word. For example, identifying instances of the word “time” in which the meaning involves the amount, allocation, or distribution of time throughout the implementation can be effectively accomplished using this approach. Time is also used as a descriptor for the occurrence of an event, such as “the last time” or “next time”, and these usages will not be counted unless the researcher believes it is relevant to the search. This method of word and phrase search was used to further examine themes discovered in the interviewing and reviewing process, and to discover themes shared by teacher interviewees which one teacher had emphasized. Using the report from the Adobe Acrobat Professional™ word search enabled a more rapid and thorough method of discovering and analyzing common patterns.

Excerpts that showed these patterns and themes were taken from the transcriptions. Those responses were reviewed finding links between the participants and links to current research and looking for themes which were not identified in the literature reviewed. The research gives us four different lenses to relate to participants’ stories.

1. School change theory: Describes the level of use as devised by Hall and Hord (2006) and asks the question, “What factors do you believe contributed to or diminished your level of use?”
2. Successful integration of a technology innovation: Investigates factors specifically contributing to the success of a technology innovation.
3. Improving teaching and learning of mathematics: How teaching and learning of mathematics changed as a result of using this innovation.
4. Meeting functional expectations: using and operating the technology and integration of the usage into the classroom.

Limitations

The study findings are limited to three teachers in high schools of about the same size and may not be generalized. The study is the work of the researcher and three classroom teachers and thus does not represent all teachers implementing innovations in their classrooms. The primary value of this study was to provide deeper understanding of the factors influencing the implementation of a content-specific technology innovation.

Chapter Four: Analysis of Results

Background

The expected outcome was an in-depth understanding of the implementation of a content-specific technology innovation from classroom teachers who were participants. A number of teachers responded to an open call through a teachers' mailing list to participate in a study to gather and analyze their perceptions of adopting the TI-Nspire™ for their classrooms. Three classroom teachers were chosen from the group of respondents because they were teaching in schools and districts that were actually part of a planned adoption. In two of the cases, the district had planned and facilitated the implementation of the innovative technology (the TI-Nspire™) and in the third case the math department of a school planned and facilitated the implementation.

The purpose of the first interview was to discover what teachers thought about their implementations: how they perceived the adoption and implementation starting; how they perceived the implementation progressed; and the factors they thought were important to the progress and success of the implementation. The second and third interviews asked teachers to examine the ideas gathered in the first interview through the lenses of the research: school change, implementation of a technology innovation, technology affecting the teaching of content, and the expectations of the manufacturer or developer.

Research Question

The research question addressed in this study was:

What were the classroom teachers' perceptions of their level of use after the adoption of a technology innovation and what factors influenced them to achieve that level of use?

Meeting the Teachers

Teacher One.

Teacher One was in a district that held meetings sponsored by the district and Texas Instruments to demonstrate the new technology and invited teachers from that district and other districts in the region to see the technology. This teacher along with other members of the math department at the high school attended some of those meetings. We'll call this teacher Teacher One and the school will be High School (HS) One. Teacher One recalls that the district promoted the new technology by offering a classroom set of TI-Nspires™ to teachers who would pilot it for two years. Part of the process was attending a 3-day workshop to help teachers decide if they were interested and to help get the process started if the decision was positive. Four of the nine math teachers in HS One joined the pilot. Teacher One was one of those.

Teacher Two.

Teacher Two is in a district that had been planning to try the TI-Nspires™ and when funds became available from a source which was unbudgeted, the entire district was invited to take part to the extent that the resource would allow. HS Two had two teachers out of sixteen members of the math department take part in that district's implementation. Teacher Two volunteered because she/he is "an early adopter" of math technology. She/He had attended some of the regional meeting demonstrating this new

technology and her/his department chair was able to get two classroom sets for Teacher Two and Teacher Two's content area partner.

Teacher Three.

Teacher Three is from a high school whose math department considers itself on "the cutting edge" of technology and Teacher Three is one of fifteen teachers who all decided as a department to adopt and implement TI-Nspire™. A few of the teachers at HS Three attended regional meetings where they were introduced to the technology innovation. They also had personal connections to a math technology trainer who was very interested in the device. After deciding to adopt the new technology, all except one of the teachers in the fifteen-member department attended the 3-day workshop to help them get started.

Interviews

In the first interview, each teacher described her (his) implementation. Teachers were slightly aware of the district projects, but chiefly concerned with the implementations at their schools. The responses in the first interview show the factors the teachers think are important to their implementation on a classroom level. Each teacher was introduced to the purpose of the study to gather and reflect on their perceptions of their implementation of the TI-Nspire™ in their classroom. They were told that they were selected from the group of volunteers because their district or school had been part of a planned implementation of the new technology. Each teacher was asked several common questions but questions were extended and expanded based on teachers' individual responses. Prompts stated and questions asked included:

- Describe the events leading up to the decision to adopt of the TI-Nspire™ and describe the implementation.
- Talk about factors thought most important to the implementation and rank those factors.
- Was your implementation of the technology innovation successful?
- Talk about factors that could have helped you be more successful.

This chapter is organized by first describing individual teacher experiences with their responses taken from the interview transcripts or the member checks as either a direct quote of the teacher or a synthesis of their remarks to focus the response. Following the individual responses are the common themes identified from all responses. The teachers interviewed had different experiences, but there were a number of themes that resulted in common patterns for all the teachers.

Teacher One's experience.

At HS One, there was initially a Texas Instruments meeting hosted by the school showing various uses of TI-Nspire. The department chair suggested that the teachers consider adopting the technology innovation. A number of them attended a 3-day workshop in Denver in the summer and learned more about the device. The district agreed to start a pilot program with each teacher who agreed to participate to receive a classroom set of TI-Nspires. Four of the nine teachers in the math department agreed to be in the pilot program.

The TI-Nspires™ have faceplates (keypads) that can be removed and the TI-84Plus™ keypad inserted so it essentially becomes a TI-84Plus™ calculator. Teacher One did not use the TI-84Plus™ keypad at all and trusted the students to learn the TI-Nspire™. The students' reactions were interesting. The lower tract kids were really inquisitive. They said, "Show me (things)!" The honors kids were threatened. Teacher One didn't try to explain why. Teacher One used the TI-Nspire in a 9th grade Integrated Math class, and a 10th Grade Algebra-Geometry Honors class. There was a third class at the senior level, but in their last year, they continued with the old technology. This teacher's approach was to have the students "just play around as an introduction -- to engage in a free-for-all with the new technology."

The 9th grade Integrated Math class "did a lot of playing around." Their first lesson with statistics was with scatter plots and lines of best fit. The 9th grade kids "were great from the get go and liked everything." A unit in linear functions was to graph by hand, but check x- and y- intercepts with the calculator. One of the most effective and fun lessons covered frequency bar graphs and box plots. Teacher One said the students love how the displays are animated. Students became fluid with scatter plots, linear regressions, and lines of best fit.

The first lesson for the 10th grade was linear programming in systems of equations. They had trouble with the window. It seemed to them to be more of a hassle with the TI-Nspire™. The tenth graders would sort of "whine" about the buttons being close together. It was "cool" when they got into linear programming with a "tns" file (the TI-Nspire™ documents are called by a name and a tns file extension such as

parkingtolls.tns). “Only a few of the tenth graders were fluid with the TI-Nspire™, they had a hard time getting intersection points and manipulating the window.” The Honors class needed more help. Only about 50% of the class could keep up. Later in the year when they studied quadratics in different forms, they would do a lot by hand, but when they were required to do situational problems and needed to figure maximums and minimums, they would add a function table and find the max and min using the table. Still later in the year in the unit on exponential equations, they used the Rule of Four and got better at manipulating the window. The Rule of Four requires the student to use multiple (4) different representations of the problem: situation, graph, table, and algebra. They liked the Ti-Nspire™ in the stats chapter, but were running out of time and it was basic skills vs. technology and basic skills won.

Teacher Two’s experience.

Teacher Two had used graphing calculators since the 1989-1990 school year which is about as long as they have been available. Teacher Two was provided with her/his first full classroom set in 1993. Teacher Two has used TI-83™ and TI-84™, and now the TI-Nspire™. Part of her interest in the TI-Nspire™ was that it was different from the earlier ones. Teacher Two related, “I tend to be on the front end of technology innovations.” To explore the new technology, Teacher Two went to some area single-day workshops and then the summer before implementation attended two 3-day workshops, one in Albuquerque and the other in Denver.

Teacher Two feels the implementation has been and continues to be slow. After the school year begins, “and I think I probably speak for a lot of teachers, if it’s not ready

when school starts, it's hard to get ready to go during the school year" because teachers get so busy. This teacher's math classes that are using the TI-Nspire™ are a pre-calculus class and a tenth-grade integrated math class. The reactions in the two classes were similar. The students were watching the teacher work with one of the TI-Nspire™ improvements, which is the use of mathematical type so the characters and symbols look like they are printed in the text book. The students asked, "Oh my gosh, can we try that?" Teacher Two stayed with activities that were "very prescriptive" meaning the teacher would give directions from process to process because the students were not very comfortable with the device. Teacher Two feels like the students still see the device as a novelty. Pre-made activities with step-by-step instructions are available on the Internet at the Texas Instruments site and other teacher-made sites. That is the content being used by the teacher.

The tenth grade integrated math class started with a pre-made golf game which requires a student to determine a function that will put a graph between two points (the ball and the hole) on a set of golf greens. They determine the function and if they are correct their graph connects the two points. They "thought it was very cool." The activities used allowed them to study what they would have studied without the TI-Nspire™, but in a different way.

HS 2 only received two classroom sets of the new devices. The other teachers in HS 2 were using earlier models of graphing calculators. Teacher Two stated that she felt the implementation would have been a different experience, possibly more complete and

easier, if all the teachers in the department were implementing the innovation at the same time.

Teacher Three's experience.

The math department at HS 3 prides itself on staying on “the cutting edge of technology.” Their involvement with the TI-Nspire™ started several years ago when the device was first introduced, guided by a retired department chair who has always led the math department in the use of technology. After that teacher retired, Teacher Three became math department manager. “We knew where technology (in math) was going, so we as a department decided” to implement TI-Nspire™. They spent a couple of years exploring and getting ready. Some of the department went to conferences, some went to summer workshops. “Last year we decided that we would start telling students to purchase TI-Nspires™” and they began a transition year. To make it easier on the students financially, they would let the students use either their TI-83™ or TI-84™ or the TI-Nspire™. The calculus class is just using the TI-Nspire CAS™. They’re not using the TI-89™ at all. “So it has been a little bit of a stretch.” Before school started all the teachers in the math department except one (15 out of 16) attended a 3-day summer workshop on using the technology and applying it to classes before school. “We got real motivated. The hard part is just finding the time to really go into it; all the activities and so forth that we know are valuable.” They found it more challenging to find the time to use the TI-Nspire™ extensively as the year pressed on. Every teacher has used the TI-Nspire™ some. “There are a lot of advantages to switching over to the TI-Nspire™, but it has been a big learning curve this year.”

Determining a Level of Use

During the second interview, these three teachers were individually introduced to the concept of Levels of Use as described by Hall and Hord (2006). The category of nonuser did not describe any of the three teachers. Users, as described by Hall and Hord (2006) are subdivided into mechanical, routine, refinement, integration, and renewal. The refinement level was self-chosen by Teacher One as describing him/herself. The routine level was chosen as the correct description of themselves by Teacher Two and Teacher Three. Within this study use levels was not a topic generated spontaneously by interviewees. The question of what level each teacher used to describe their progress in the implementation primarily verified that the participants in this study were selected correctly.

Finding Common Themes

The teachers interviewed had different experiences, but there were a number of themes that resulted in common patterns for all the teachers. A summary of teacher responses is shown in the following tables and the common patterns are noted in the left hand column. Each of the common themes (limited time in a teacher's day; change is a process that can take years; administrative support is secondary but important; professional development is critical and should be ongoing; technology in teaching and learning is essential; classroom practice improves because of technology implementation; and technology features used depend on the content taught) is examined by looking at all the excerpts from the interviews that mention the common theme. Where appropriate, the words used in a word search to fully develop the common theme from the teachers'

perspectives are on the left. That word search assured that all the instances of that word relevant to the thought being highlighted were found.

Time in a teacher's day for implementation is limited.

One of the most constant themes in the teachers' interviews was a topic that a person involved with teachers or teaching hears constantly. There is hardly ever enough time in a teacher's day and once the school year starts, there's very little time for anything else than the students and the classroom. Using the word search for the words "time", "busy" and "overwhelming", it was possible to track what teachers were saying about time and connect that theme that teachers are busy with teaching; implementing an innovation takes time (time to plan, to use, and to collaborate); and finding that time is a challenge. Furthermore once the time is found and scheduled, the time needs to be protected from all the other demands placed on teachers as they not only attempt this innovation, but grade papers, plan lessons, talk to parents, and perform tasks for administration, other teachers, and students. As *Table 1* shows, each teacher expressed the theme in different ways, but the common idea that implementing an innovation takes time: -- time to learn, time to plan, time to use, and time to collaborate, and that finding the time is a challenge was possibly the strongest common theme voiced by the teachers. A summary statement by one of the teachers was, "time is a biggy." The importance of this factor in this study and to teachers is that the implementation planner, manager, and classroom teacher need not only be aware of teachers' limited time, but to structure the implementation appropriately to account for the limitation. Once the implementation has begun the administrators including the building principals and department chairs need to

Table 1: Analysis of Teacher Responses – Limited Time in a Teacher’s Day

	Teacher 1	Teacher 2	Teacher 3
<p>Relevant instances of mention of time 23 times by all three participants.</p> <p>Word Search Terms: time, busy, overwhelming</p> <p>Common pattern: Teachers are busy with teaching, implementing an innovation takes time: time to learn, to plan, to use, and time to collaborate; and finding that time is a challenge.</p>	<ul style="list-style-type: none"> ■...running out of time... ■...catch up time... ■...it takes more time to show them how to do something. ■Collaborating, coming up with activities to use, times of the year it would be ideal to try something... ■(We) Were going to try to do something after school, but (were) too busy. ■time before school year started ■so much on our plate 	<ul style="list-style-type: none"> ■...once the school year starts; it takes time and is hard to do. ■...time to download files... ■It’s good collaboration time. It’s good to have somebody working through this with you. ■...if it’s not ready when school starts, its hard to get it ready to go during the school year because things are just...I mean there’s school...busy. ■you have to allow time ■have time dedicated to implementation ■time is a biggy ■PLC time is protected ■time and effort figuring out what these can do 	<ul style="list-style-type: none"> ■They found it more challenging to find the time as the year pressed on. ■Time throughout the entire year would have really helped and would make us more successful. ■time to try to find...and really incorporate them ■additional time to work through it ■a timeline might be helpful ■time to sort of review what research has been found ■time to try them ■a time factor for teachers as teachers right now are so overwhelmed

protect the time associated with the implementation. Teachers need to protect their own time. Teachers perceived that without adequate time, the success and level of the implementation was affected.

Implementation is a process that can take years.

The second common theme that was suggested by previous research and also confirmed by this research is that change is a process, not an event. In fact, the teachers interviewed for this study elaborated on that theme and their thoughts extended the emphasis. Implementation is a process that may take years. It does not end with the orientation workshop or the adoption of the innovation as an event, but continues, sometimes slowly, as it is incorporated and accepted by the students and other teachers. After the first year, all of these teachers felt they were just getting started. However, they also felt that they had become constant users and would not revert to similar older technologies.

Table 2 indicates that teachers are talking in a voice that shows that they internally think of the implementation as a process, not something that happened at one specific time or event. Throughout the interviews teachers talked in terms of “this year.” The verbs were not past tense, but portrayed a continuing effort. None of the teachers, at the end of their first formal school year of the implementation, viewed themselves as finished. In fact, they viewed their school as just beginning to implement the innovation. Their responses to a specific question concerning activities and events showed they considered each separate activity or event to be just part of the implementation. Each teacher had definite goals for the following year.

Table 2. Analysis of Teacher Responses – Implementation Is a Process that Can Take Years

	Teacher 1	Teacher 2	Teacher 3
<p>Relevant instances of words by all three participants. Next year; process;</p> <p>Common theme: Implementation is a process that may take years. It does not end with the orientation workshop or the adoption of the innovation as an event, but continues, sometimes slowly, as it is incorporated and accepted by the students and other teachers.</p>	<ul style="list-style-type: none"> ■The process of the kids becoming really comfortable with the calculator? ■Ideally meet in the summer and go through some of the activities that are created, work with teachers in the same subject, add more questions. ■Start before the year starts, tweak activities, fine tune together (as the year goes on). ■if you have a plan in writing for an implementation, you might consider the process more systemically, more systematically 	<ul style="list-style-type: none"> ■I certainly have teaching long enough, at least in my opinion, change is a process and not an event. ■You have to have time to process what that something is, and to incorporate that into your teaching, and make sense out of it ■...going to be our way for the next year. Well the ■implementation has been and continues to be slow in the classroom. So I'm hoping for better next year. ■Particularly if we're ready to start the year using the Nspire faceplates... ■My hope is that one more school year. 	<ul style="list-style-type: none"> ■...a TI Instructor would help us implement it a little more next year. ■...start really using it every day in my classroom because next year we should have all the students having Nspires. ■... are hoping to get to refinement maybe next year. The classes that I taught because they are in that transition piece the students had TI-84s and Nspires ■We're still in that process of implementation. You know we have kids with calculators. We use those calculators in our classrooms every day. And were still trying to do what ... create our lessons around those calculators, but we still have a long way to go. ■...it's definitely is a process, sometimes a frustrating one in regards to you don't know how this works and it takes a little bit of extra time out of your class, out of your planning to implement it

Administrative support is secondary but important.

The responses regarding administrative and school leadership support show that from the teachers' perspective the school and district administrations were not actively involved in their implementations. *Table 3* shows excerpts from the interviews concerning principals and administrators. All principals were seen as taking a 'hands-off' approach to the implementation except when support was explicitly requested. None of the teachers indicated they asked for active involvement from their administrators at either the school or district level. All three teachers indicated more administrative involvement could have been helpful, but did not seem to be dissatisfied with the level given to them. Part of their response included implementation decisions are best made at the classroom level, either as an individual teacher or a content-area department. Teachers indicated administrative actions to support change adoption might be most helpful if used to involve entire departments or more teachers and also to protect implementation time from intrusions.

Professional development is critical and should be ongoing.

Teachers spent significant time talking about professional development. *Table 4* illustrates this theme. The common theme is that professional development is critical from pre-implementation and continuing during the entire implementation. Following their initial interview responses each teacher indicated they had been to one or more pre-implementation workshops. When asked directly about the value of the pre-implementation workshops, they noted workshops were critical to being able to get started.

Table 3. Analysis of Teacher Responses – Administrative Support Is Secondary but Important

	Teacher 1	Teacher 2	Teacher 3
<p>Relevant instances of words by all three participants. Administration, administrative, principal, superintendent</p> <p>Common theme: The principal or school administration was not involved much except to support the department decision to implement the technology. Even in the case of the whole school adoption, it was students who were buying the bulk of the TI-Nspires. Each supported more administrative involvement, but wanted the decision and the implementation to stay at the department or classroom level.</p>	<ul style="list-style-type: none"> ■Administration not involved at all except to pay for conferences. Principal didn't seem to care at all, didn't seem to know much about it. ■District administration paid for workshops. ■Interesting question, you know if I think it would be a good thing for the administration to be more involved, it might be a good thing if the administrators were pushing the other teachers in the department to attend TI workshops and to have been involved in the pilot and to have been using the newest technology but as you said, they're really not involved, they're really hands off. ■At one point last year one of my evaluators was a former math teacher. She had some good questions... ■We just agreed to try it out and you know we did actually have someone in the district that was we were supposed to reference and she was working on getting calculators in other schools in the district but time flies by when you are teaching and we didn't really use her much 	<ul style="list-style-type: none"> ■Not really, but in a way...that's not true. They were involved. We have a principal that puts a great deal of trust in our department to do the right things so even that hands off approach is supportive. But he also paid for me to go to the workshops so absolutely. That was supportive. ■ School administration paid for workshops. ■Certainly (the math specialist) at the central office has been a real go-to person. ■Especially right now in Colorado when you've got to unpack all those new state standards and everything else, so I have great respect for our math specialists that I think right now he's weighed down by so many other responsibilities, that he has left the technology pieces to the school. 	<ul style="list-style-type: none"> ■When we decided as a department that this is where we wanted to go, we did consult with our administration about implementing it. ■ School administration paid for workshops for all teachers in the department. ■It's more important to make sure teachers are onboard first, and then make sure administration is going to support you. ■Our administration is very supportive of technology ■No assistance from the district administration.

Much of the ongoing professional development was collaboration between the members of the implementation teams. Teacher One had a team that included four teachers. This team was not formal, but each member was available and one was considered the most knowledgeable about this innovation. Teacher Two had a team of two teachers and they worked together to implement the innovation in their classrooms. Teacher Three was in a math department in which all teachers were implementing the use of the innovation. The support and ongoing professional learning community structure was important to them. They used each other as their outside resources and when asked about what they would want for the future, they responded with a need for continuing professional development, primarily in how to integrate the technology into their curriculum and for help with particular functionality.

From the research by Zhao et al. (2002), we know availability of outside experts and consultants is one of the factors affecting the success of the implementation of a technology innovation. Each responded in a positive nature about using live online “webinars” and developing online and face-to-face PLC’s with other teachers implementing the new technology. In discussing the PLC format and continuing professional development, one of the teachers talked about how the most important professional development during her long career was one a quarter for two days, the group repeatedly over a four-year period came back, reflected, and discussed and then proceeded with their work.

The teachers used the pre-implementation workshop to learn how to operate the devices and software. Then they used the PLC format to work together and use online resources to integrate the new technology into their curriculum. Their call for ongoing

Table 4. Analysis of Teacher Responses – Professional Development Is Critical and Should Be Ongoing

	Teacher 1	Teacher 2	Teacher 3
<p>Relevant instances of words by all three participants. Training, professional development, training, workshop</p> <p>Common theme: Professional development, from pre-implementation and continuing during the entire implementation is critical.</p>	<ul style="list-style-type: none"> ■ went to one short workshop and one long 3-day workshop and another short workshop – pre-implementation workshops were pretty important. The long 3-day workshop was very important. I would have been lost without going to both the workshops ■ some more professional development now that I've use it – still tricky to figure out how to do things on their own ■ not successful without the workshops – an expert in the room 	<ul style="list-style-type: none"> ■ at least the initial one, the 2 day would be critical for anyone wanting to (implement) ■ two one-day events, a 2-day workshop, and a 3-day workshop ■ my implementation partner has not had the official training, but I hope that will happen ■ best professional development included college credit, once a quarter for two days, continual for 4 years...came back, and reflected and discussed and proceeded and reflected and discussed and proceeded ■ want a more real time, as needed professional development ■ PLC model might work well in a webinar type of situation ■ Our PLC time is protected 	<ul style="list-style-type: none"> ■ Without the in-depth (pre-implementation) workshops, that would have made it really difficult. (We went as a department and) during the workshop we collaborated a lot about how we would use it in our classes. ■ Then again we would really maybe like to get a little bit more training. No so much training on the calculators, but just how to find the time to implement those activities. Actually go through our curriculum and try to find activities that fit into what we were doing before. ■ helpful to continue on with workshops

professional development did not omit learning about advanced operations, but did concentrate on classroom and content integration primarily.

Technology in teaching and learning is essential.

The teachers formulated a common theme regarding the use of technology in teaching and learning mathematics. See *Table 5*. The teachers stated that technology has changed the way they teach; they use more applications and more real-life problem solving situations. Technology allows for better visualization, animation, better multiple representations, and more precision. One teacher wonders about students being so reliant on technology, but another says the students are so “techno savvy” that it is part of their lives now and they need to be using it in all facets including mathematics. That difference in this sample of three teachers tends to illustrate one of the major debates in the math community.

Teachers talked about using interactive geometry applications in which a figure can be constructed and then moved to show many instances of a property. They mentioned the importance of having the capability to change types of representations of data from histograms to box and whisker plots instantly. The technology allows the student to add a line of best fit to a scatter plot and experiment with its placement and see its changing algebraic formula. They mentioned data collection, spreadsheets, and graphing. The ability to simultaneously view multiple representations of functions is the feature most commonly mentioned by teachers. These are all changes which are either new capabilities afforded by the TI-Nspire™ or sufficiently upgraded in the new technology to now make the old technology seem unusable. A good common example of having

Table 5. Analysis of Teacher Responses – Technology in Teaching and Learning Is Essential

	Teacher 1	Teacher 2	Teacher 3
<p>Relevant instances of words by all three participants. Animate, visualize, problem solving, accessible, multiple representation, proof</p> <p>Common theme: Technology has changed the way we teach; we use more applications and more real life problem solving situations. Technology allows for better visualization, animation, and better multiple representations and more precision. One teacher wonders about kids being so reliant on technology, but another says the kids are so “techno savvy” that it is part of their lives now and they need to be using it in all facets including mathematics.</p>	<ul style="list-style-type: none"> ■ use it to reinforce what is learned as far as rates, quadratics, exponential functions, trace, tables ■ quicker using technology, accomplish more in a short amount of time ■ better for more tactile learners ■ use it for checking solutions, with a graph or table, line of best fit - reinforce ■ no math more accessible ■ geometry page and bisect angles, constructions ■ so reliant on the calculator at our school ■ Their data and statistics window, how it can go really quickly from a histogram to a box and whisker; and the kids really respond to how it is animated and the line of best fit and linear regression; and I like how they can label their dependant and independent variables within that menu, that is a really cool feature. 	<ul style="list-style-type: none"> ■ the ability to see multiple examples of something quickly ■ see the effect of every parameter in that equation on that function ■ I have come to view it as important in the development of proof ; idea of being able to inductively see how things are working how this led to more interest in deductive proof for kids at least in my classroom. ■ the preciseness that technology offers again leads kids to make some aha and generalizations that they may not otherwise make ■ if we weren't using it in this day and age that we would lose kids that are just so techno savvy that that is a part of their lives now and they need to be using it in all facets of their lives including math 	<ul style="list-style-type: none"> ■ helps it (math) be more visual for students ■ helps to attract the different learning styles a student may have ■ kinesthetic and kids are actually working on putting things in their calculator and involving them ■ look at problems in a lot more depth than they could be without using the technology ■ So it really has changed the way that we teach and I can't imagine not having that kind of technology in my class. I use it every day. ■ more concerned with the applications and really how to handle life with mathematics and that really opens up maybe more problem solving type situations that before you really could not explore so

new technology make old technology seem useless is the switch many years ago from black and white TV's to color.

Classroom practice improves because of technology implementation.

This sample of teachers varied as to their functional use of this technology. The common theme around the changes in classroom practice and process which were attributable to the new technology centered, understandably, on their uses of technology in teaching math. *Table 6* summarizes their responses about changes in classroom practice and process that were attributable to the new technology. According to their responses in the interviews, this technology innovation has changed classroom procedures and process by improving the visualization especially of multiple representations through split screens and by adding animation that engages students. The use of investigations has been improved by enabling students to explore more, show scaffolding in problem solving using the page feature of the new technology, enabling the creation of investigations and tailoring ones which are downloaded from the Internet, and generally improving the discovery approach.

The new technology enables use of computer applications without needing to go to the computer lab or bringing in a portable set of computers. Neither the trip to the computer lab nor bringing in a portable set of computers is effective for a technology that is integral to instruction. The labs are shared and even if the math department in these schools had a dedicated math computer lab, they would be shared by more than ten teachers. If all teachers were using technology in their classes, they would need to wait for more than two weeks to get their one-period share of the lab.

Table 6. Analysis of Teacher Responses - Classroom Practice Improves Because of Technology Implementation

	Teacher 1	Teacher 2	Teacher 3
<p>Relevant instances of words by all three participants. Math, Learning, Teaching, Software, Split, Animated, Pages, Documents, Lab, Activity</p> <p>Common theme: This technology innovation has changed classroom procedures and process by improving the visualization especially of multiple representations through split screens, adding animation which kids respond to. The use of investigations has been improved by enabling students to explore more, showing scaffolding using pages, creating investigations and tailoring ones which are downloaded in a problem or investigation, and generally improving the discovery approach. The new technology enables computer applications without needing to go the computer lab or bringing in a portable set of computers.</p>	<ul style="list-style-type: none"> ■ used software and projector instead of the overhead projector ■ split the screen to show simultaneous changes in one representation with changes in another ■ used previously lap-type software in class without going to the lab ■ downloaded content to share with students using Connect to Class ■ kids really respond to how it is animated ■ can find an activity ... download it and connect it ... quickly to your classroom set and the kids can work through an activity or an investigation ■ without having to go to a computer lab. You can do it right in your room ■ have the graph and your table on one screen 	<ul style="list-style-type: none"> ■ I think this idea of even just the pages in a document and simply being able to work through a problem much as you would work through the pages in a book ■ the kids can see the scaffolding of what is going on in that problem and that investigation ■ the split screen; that capability and to see how the change in one is truly affecting the change in the other ■ ability to create those investigations and tailor those investigations to my kids and my curriculum in my classroom ■ nice not to have to go to the lab 	<ul style="list-style-type: none"> ■ a good thing is the capability it has with documents. You are able to let students explore a little bit more on their own rather than just be more teacher led. ■ allows for more of a discovery approach for the students and I think that is a big improvement for this innovation can do rather than a regular calculator. ■ level of problems students can look at definitely changes ■ You are not so concerned with the drill and kill of solving a problem but more concerned with the applications and really how to handle life with mathematics and that really opens up maybe more problem solving type situations that before you really could not explore so much and so I think that is what this new technology is bringing into the classroom.

Technology features used depend on the content taught.

The features of the innovation which were used by these teachers are shown in *Table 7*. The most common of those was using documents. This feature was one of the developer's chief concerns as it was seen as affecting "deeper opportunities to learn" (SRI International, 2006, p. 1). The teachers downloaded documents that were authored by other teachers and Texas Instruments writers and placed on the Texas Instruments web site. Some of those documents were edited to better reflect the teacher's curriculum, but these teachers did little authoring of their own documents and did not electronically capture documents that the students had created. Each teacher used the documents for students to work on problem solving or investigations. The level of problem presented seems to have become higher as time went on and the teachers used the pages for "scaffolding of what is going on in that problem and that investigation."

Teachers mentioned taking advantage of the split screen to see multiple representations change immediately instead of having to change views as they did with the previous technology. They all three used technology that they would have previously needed to take their class to the computer lab to use. They mentioned several problems with access to the computer labs that made this aspect of the innovation very valuable. The teachers used a variety of features that were available on the TI-Nspire but were not available on the previous graphing calculators. No single teacher used all of the new features, nor all of the same features as the other teachers. They used, understandably, the new features that were appropriate for them and their classes. This has impact on the creators of professional development workshops and professional learning communities to connect content to specific classrooms or at least teachers with appropriate

Table 7. Teacher Responses. Technology Features Used Depends on the Content Taught.

	Teacher 1	Teacher 2	Teacher 3
<p>Relevant instances of words by all three participants. Documents, pages, animation, inequalities, spreadsheet, multiple representations, geometry, activity, Connect to Class, grab, content</p> <p>Common theme: Implement the new technology as you need it in the classroom. Connect to Class has been used to transfer files to students, but not to retrieve files or formative assessment from students. The visualization and animation has been used. The online content has been used in class.</p>	<ul style="list-style-type: none"> ■ teacher software on the computer for projection ■ graphing, data and statistics – choose plots quickly and line of best fit and choosing dependent and independent variables ■ graphing inequalities or doing a linear programming problem, shade correctly ■ kids respond to animation ■ split screen, graph and table on one screen ■ Find an activity and download it, an activity or investigation ■ Geometry part cool ■ Don't have to go to the lab ■ content by Connect to Class ■ spreadsheet to enter data ■ on graphs, click on a point and type in the other point intersection points, corner points in feasible regions, ■ box and whisker plots, frequency plots, and scatter plots ■ used to be signed up for MathNspired.com, but go to activity exchange 	<ul style="list-style-type: none"> ■ spreadsheet looks like a spreadsheet and use it in that way ■ math print ■ split screen experiments the multiple representation experiments have been used investigations ■ geometry capabilities ■ Connect to Class to I used it for was to change to edit investigations. ■ the grab and move ■ 3 different activities that I used during our the quarter ■ we didn't have to go to the lab ■ got content from the Internet; they are just right there and you are like oh wow that would be a cool activity to use you know with the kids 	<ul style="list-style-type: none"> ■ Connect to Class (file transfer tool to students from the teacher) ■ our geometry content team have used some of those features (interactive geometry) ■ portion, yes, we do use that you know to generate the list and so forth and to transfer those variables right over to your graphs or your data and statistics page so that has kind of been a nice feature ■ The students are able to understand what their variables are and what those graphs look like when you switch them. ■ a lot of analyzing the graphs, I mean max, min and zeros and inflection points ■ A lot of times if we have students collect data. Then we would put that in and have them fit a function to it. ■ We have used some of those (downloaded content pages). ... I think that is where we're lacking is finding the time to try to find those things and really incorporate them into our curriculum.

commonalities. Connect to Class was used to transfer files from the Internet to student handhelds, but only in class by two of the teachers. The third teacher has solved the technical problem and will use that feature next year. Each teacher used classroom-ready content from the developer's web site.

Summary Question from the Interviews

The third and final set of interviews focused on the teachers making meaning of their experience (Seidman, 1991, p. 14) and developing links to research. Two questions asking teachers to make meaning of their experience preceded a third question meant to help them personalize the important parts of the experience, but also enabling the teachers to generalize for other teachers and administrators who will in the future implement a content-specific technology innovation. Throughout the process of conveying their experiences and verbalizing their thoughts, they were ready to talk about what they thought other teachers would want to know. The last item in the interviews for all the teachers was to imagine a written implementation plan. What factors would they include in such a plan? This strategy helped identify factors they thought would be most important for other teachers or groups of teachers to consider in implementing a content-specific technology innovation. Their responses are collected below in *Table 8*.

Key Implementation Factors

Each teacher started with discovery workshops that introduced them to the innovation. The teachers see strength in numbers and emphasized that as many teachers as possible should be involved. If possible, the whole department should be recruited. Although they seemed to generally think that change for them happens at the classroom level, they see that without the whole school, or department for a content-specific change,

the change will not last and not be of as much value for the students. After they had decided to adopt the innovation, they attended in-depth workshops so they would be ready. The reactions to these pre-implementation professional development activities were that they were critical for anyone wanting to implement an innovation; that they would have been lost without going to both the workshops (one introductory, one professional development); and without the pre-implementation workshop, implementation would have been really difficult. Still preparing for the implementation, they would make sure all the technology they needed was in place. Each had a full classroom set of devices which they thought was a minimum requirement. Before the implementation, they thought the best way to communicate the planned implementation to the school community was for each teacher to explain the change to students, but they also considered telling parents at a back to school night why they considered the change important. The schools also have web sites for communication with parents, and the teachers recommended use of this medium as well.

A common theme was to set up a support system, a sharing resource. Most teachers are familiar with the PLC concept even if they don't use it in their schools. The need to ensure that time is available and that it is protected either by structure and/or administrative assistance is paramount. The beginning of the implementation for them was to look for activities online or in the developer's resource material. They would begin their PLC meetings and continue throughout the implementation. They emphasized the "continual" part of continual professional development and that professional development should continue throughout the implementation. In this desired

Table 8. Teacher Responses: Summary Responses to Developing a Written Plan

	Teacher 1	Teacher 2	Teacher 3
Common theme: Key Implementation Factors	<ul style="list-style-type: none"> ■ pre-implementation workshops were pretty important. The long 3-day workshop was very important. I would have been lost without going to both the workshops ■ written plan ■ quick reference guide ■ there is so much on your plate, ... last minute project, so just implemented when we could ■ mentioned at back to school night, so it's a great calculator to buy if they don't have one ■ sharing time – short, off-the-cuff, sat in on a class, sit down together and explore the developer's web site, ... just share by email ■ try to download one investigation for each unit ■ what can I use ■ try to find time before school starts and during school to share. Find activities to use and share. ■ an online webinar resource would help ■ just let them play around it and see what they can figure out 	<ul style="list-style-type: none"> ■ at least the initial one, the 2 day would be critical for anyone wanting to (implement) ■ recruit as many teachers as possible ■ have access to all the technology needed ■ replace the old with the new, don't use both ■ have each teacher impress to their kids that this is the way we are going and why ■ tell parents why at an open house or back to school night ■ scaffold the implementation ■ present the written plan in a notebook ■ protect implementation time, suggest once a month ■ PLC (support) including webinars ■ assessments aligned to and including use of the new technology ■ continual professional development – train, try, reflect, discuss, and train again, as long as 4 years ■ you have got to allow time for that because people are not going to again they just fall back to what is comfortable if it is too hard for them 	<ul style="list-style-type: none"> ■ Without the in-depth (pre-implementation) workshops, that would have made it really difficult. (We went as a department and) during the workshop we collaborated a lot about how we would use it in our classes. ■ make sure all teachers are willing ■ start the plan with a conversation among the teachers then incorporate that conversation with the administration to get their and community support ■ 2 to 4 years to get them teaching solely with the new technology ■ time line – its not going to happen overnight ■ helped in guiding teachers ■ what to look for and what problems you might encounter ■ communicated with the parents by a school web site ■ first step, look at accessibility to computers or calculators ■ a short review of research in the content area ... would help people understand and help sell the plan ■ continuous incorporation, feedback, webinars, get the information out in a way they don't have to use a lot of time. ■ short sharing times – full days probably not possible because of other priorities

ongoing professional development, they thought that live online meetings with experts, online tutorials, and online data banks would be important. They shared the view that one year was not enough and generally the view was that two to four years is needed to really make a technology innovation into a fixed classroom procedure.

Chapter Five: Discussion

This chapter will discuss the perspectives of the classroom teachers who have implemented new technology in their classrooms as seen through the lenses of school improvement, implementing a technology innovation, technology in their content area, and possible functional uses of the technology, and summarize and discuss the common threads which illuminate their focus on the technology implementation. A conclusion will use the teachers' perceptions to suggest how implementations of technology for content teachers could be improved and suggest further ideas for research. *Figure 2.* summarizes the four research areas and the teacher's focal points.

School Change Theory (Hall & Hord, 2006)	Implementation of a Technology Innovation (Zhao, 2002)
<ul style="list-style-type: none"> ✓ Change is a process, not an event. ✓ There are significant differences in what is entailed in development and implementation of an innovation. ✓ An organization does not change until the individuals within it change. ✓ Innovations come in different sizes ✓ Interventions are the actions and events that are key to the success of the change process. ✓ There will be no change in outcomes until new practices are implemented. ✓ Administrator leadership is essential to long-term change success. ✓ Mandates can work. ✓ The school is the primary unit for change. ✓ Facilitating change is a team effort. ✓ Appropriate interventions reduce resistance to change. ✓ The context of the school influences the process of change. 	<ul style="list-style-type: none"> ✓ Your general technology proficiency ✓ Technology compatible with your pedagogy beliefs ✓ Your knowledge of your school 's culture ✓ Teachers and students needed to learn a lot to use the TI-Nspire ✓ Use needs a big change in current classroom practice ✓ Supporting state of technology in the school ✓ Needed to rely on other people to implement the TI-Nspire ✓ Needed other technological resources to implement the TI-Nspire ✓ Human infrastructure support ✓ Presence of a "translator" who helps with understanding and use of the technology

Figure 2. Content-Specific Technology Innovation Implementation through Five Lenses

Figure 2 continued:

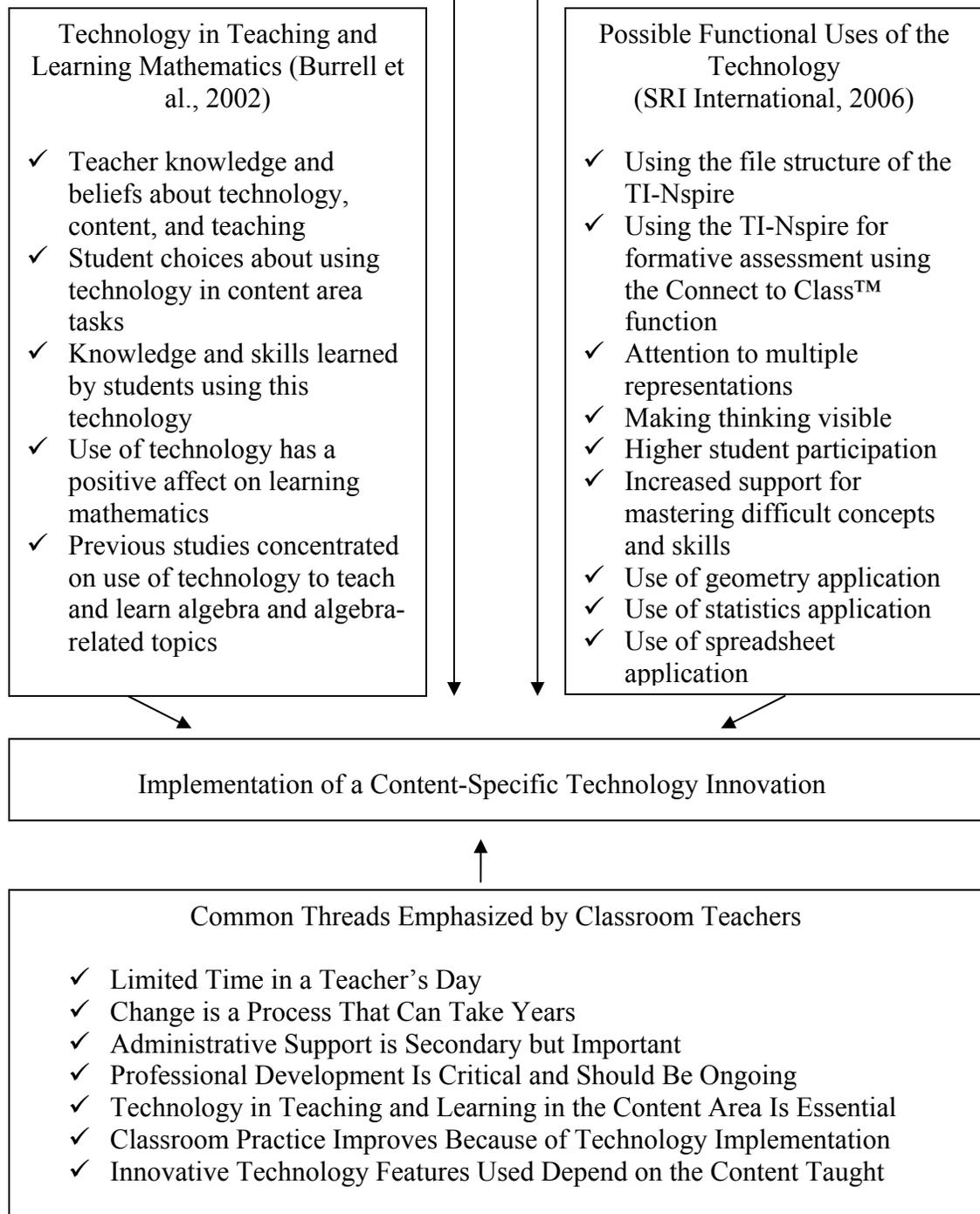


Figure 2. The Content-Specific Technology Innovation through Five Lenses

Classroom Teachers Looking Through the School Improvement Lens

The research on school improvement focused on Levels of Use and Twelve Principles of Change (Hall and Hord, 2006). The concept of their level was not mentioned by the classroom teachers until asked specifically to identify a level after showing them a brief summary. They focused on three areas of the twelve while describing their implementations. They emphasized that change is a process, not an event; they discussed the administration's role; and each teacher was part of a formal or informal team they referred to as a PLC.

Their view of change as a process is viewed in years, not semesters. While those of us outside of the classroom tend to see smaller divisions, these classroom teachers envisioned a year for getting started, a year for improving the approach, and a year to become fully competence and complete integration. The plans hinted at recognition of this implementation taking years, but included few realistic expectations and goals that matched the teachers' perceptions. A working recognition of how these teachers view school years would have guaranteed support and third year of their implementation with the first year learning to functionally use the technology and begin to integrate it into the curriculum; the second year might have a goal of becoming proficient with integration into the classroom; and the third year modifying the use of the technology to match the department needs and developing expertise so that changes in usage are seamless in the future.

The classroom teachers each saw their individual or department level as most important relative to adoption and implementation decisions. However, as a group, they

agreed that if the implementation was to be relatively permanent, it needed to be implemented by all teachers in the department. That is equivalent to viewing the department as the primary unit for change when considering a content-specific innovation. Teachers felt that they, rather than administrators, should determine the importance of the decision to implement because they were responsible for classroom implementation. They did note administrators should play a role in encouraging department-wide adoption, protecting the time dedicated to implementation for several years, and communicating with parents and others outside the classroom teachers' department. Teachers agreed that context of the school influenced the implementation. In each of these teachers' view, their schools fostered change.

Each teacher emphasized how critical the professional development was in getting started, but then shifted to their use of a PLC to learn from each other during the implementation. The PLC structure seemed to be largely formal in these schools, but in a school which does not have a formal structure for implementation and learning teams, these teachers implied that formation of teams would be important. Not only did the teachers did focus on the importance of having someone to work with during the implementation, but each agreed that if the whole department were implementing, the task would be easier and the change would be more permanent.

While the verbalization of the principles was different, a number of the principles were recognized by the classroom teachers although not focal points of their implementation experiences. The focus was not on the planning such as the difference in development and implementation, interventions, mandates, reducing resistance to change,

changing the organization because they were not involved in planning the overall adoption and implementation, just what was happening in their classroom or at the most the several classrooms in their professional learning community.

Classroom Teachers Looking at Implementing a Technology Innovation

Only one teacher thought that her (or his) implementation was not held back by technology problems. Those problems were secondary to other concerns such as time to fit the implementation into the rest of the demands on the classroom teacher. The domains that Zhao et al. (2002) envisioned of the innovator, the innovation, and the context of the innovation were not explicit focal points for them. However, they very easily recognized upon questioning that the factors in these domains were relevant. Each teacher saw themselves as technology proficient with technology in their content area. Each used similar technology in their classroom before implementing the innovation, so technology usage and pedagogical compatibility were positive. If there was an area that was not clear to them it was their command of their professional environment. It remains to be seen what the results would be if teachers who did not see themselves as technology proficient and had never used technology in their classroom had been part of these implementations.

The innovation domain factor of distance played roles in these teachers' implementations. Zhao et al. (2002) says the most successful projects tended to depend on the least technology out of the control of the innovator (p. 501). When questioned about their background these classroom teachers implied that the innovation was an extension of graphing calculators. At least one had used similar geometry software in

class. The teachers didn't feel there was much distance from their current classroom practice. The teachers seemed to feel that was important. However, some of their uses were innovations compared to their use of graphing calculators. At the end of the first year they felt they were just getting started, so there was some unrecognized distance to travel before arriving at a desired level of use.

The department implementation felt little dependence on either instructional technology technicians or outside instructional consultants to integrate the technology into their classrooms. They did depend on available online resources for content. The other two had some problem with technology. One was significant and that problem was depending on others who had to get permissions. That indicates that some of the dependence problems might be caused by lack of authority to just solve a problem without asking permission. Zhao et al. (2002) state their conclusion that the most successful projects tended to depend on the least technology out of control of the innovator (p. 501). When the technical infrastructure was not sufficient, as in one teacher's case, the innovation could not be used to its fullest capability. There was generally dependence on inside and outside sources, and these teachers' experiences showed that assistance should be planned into implementation projects and control transferred to the innovator or a person as close to the innovator as possible.

For these teachers the school context was friendly. There were people to help, there were team members working on the implementation, and the school atmosphere enabled technology innovation. That indicates that all the factors discussed by Zhao (2002) are important to the classroom implementation.

Classroom Teachers Looking at Technology in the Content Area

The research on using graphing calculators, the closest “cousins” of the new technology concentrated on measureable results. In summary, again, the literature and studies on graphing calculators concentrated on algebra topics. (Burrill et al., 2002; Ellington, 2003; Heller et al., 2005; Khoju et al, 2005) The studies showed significant positive effect on student learning when students are using graphing calculators. (Ellington, 2003; Heller et al., 2005; Khoju et al, 2005) This study addresses change due to the introduction of a new technology in the mathematics classroom. An important change would be teachers’ use of the new technology in mathematics classes other than algebra and courses which directly depend on algebra.

The classroom teachers were not so impressed by the “significant positive effect on student learning” as measured by student test scores as they were that technology has changed the way they teach; they use more applications and more real life problem solving situations. Technology allows for better visualization, animation, and better multiple representations and more precision. One teacher wonders about kids being so reliant on technology, but another says the kids are so “techno savvy” that it is part of their lives now and they need to be using it in all facets including mathematics. They are effectively saying for students born since the commercialism of the Internet and the release of the first graphic user interface World Wide Web browser, that no one should think a classroom void of technology will be sufficient.

Classroom Teachers Looking at Their Functional Use of the Innovative Technology

SRI International (2006) reported that the TI-Nspire™ could improve effectiveness in the math classroom through the improvements in the graphing calculator and the use of formative assessment capability of the use of the Connect to Class™ connectivity. Enhanced representation and communication of important mathematics were a possibility with the new technology. TI-Nspire's™ linked representations should help teachers to focus students' attention on the relationships among multiple representations, such as algebraic equations, geometric constructions, graphs, and tables. TI-Nspire's™ multiple representation and communication capabilities can make thinking visible and can support the classroom teacher to engage students in doing and discussing important mathematics. Students should have deeper opportunities to learn. Using the new document features of TI-Nspire™, teachers can develop classroom practices that increase the time students spend doing mathematics in an environment that has the ingredient for success: increased support for mastering difficult concepts and skills; high student participation; and tools for reflective practice.

The teachers implemented the new technology as they needed it in the classroom. Referring to the table in Appendix A, many of the possibilities enumerated by the SRI study can be matched to these teachers. Connect to Class™ has been used to transfer files to students, but not to retrieve files or formative assessment from students. The visualization and animation has been used. The new animation features captivate and engage students. The online content has been used in class. Generally these teachers are making use of the generalized possibilities of the innovation. In terms of specific

features such as statistics graphing, interactive geometry, or improved calculator templates or functions, those are used by teachers according to the content they teach. Establishing a list of features and capabilities like Appendix A would help teachers establish specific goals and move from practices they have used previously to new features they could integrate into their instruction.

The Foci from the Teacher's Reflections

If these classroom teachers were leading implementation of a technology innovation, the emphasis would not be abstract; the plan would concentrate on having time to learn, time to plan the use in the classroom, time to let students explore and learn, time to reflect, time to repeat the process over and over for a long enough span for it to become the technology used.

Scheduling and Time.

Teachers plan the year; they begin with the end of the year in their minds. Before the year begins they grab a new idea, explore it, and have some idea of how they are going to use it in class. If that starting point is moved to a different point in the year, their, the calendar is violated. Once school has started, the teacher is focused on carrying out the plan and responding to the new class of students. Every year there is a new class of students. Every year the teacher has to respond to their needs, not last year's needs, not planned needs, not some set of fictitious students from a research project. That is the teacher's life. If we are going to implement new technology in the teacher's classroom, a primary finding of this research is we should try our best not to violate the teacher's calendar and plan around them.

If a classroom teacher were planning implementation of a technology innovation, the plan would include having everything ready to go at the beginning of the year. The all of the technology components would be in place, and also the plan for monitoring and fixing the technology would be in place. The components include computer hardware and software, the networking availability and accessibility, the peripheral connectivity, and the communication of all these parts with the new device and/or software program needs to be considered. There is no time to focus on creating the correct mesh of devices or instructions for the use of a new device once the school year has started.

Professional Development and Teacher Commitment.

Classroom teachers note that the initial in-depth professional development needs to be done before the school year starts; professional development is critical. It would be best for professional development prior to the start of the school year to include developing an outline of how the innovation is going to be used in the classroom and those initial activities and that initial orientation for the students who will be the focus of the new innovation. The classroom teacher would tell you that their focus is on the new class of students, not innovation, once school has started.

A technology innovation that requires school and district resources and year round professional development and instructional technology resources, requires a high level of teacher commitment. Such teacher commitment is gained by making sure teachers are supported in attending content conferences where initial contact is probably made and that teachers are funded and otherwise supported to attend exploratory workshops that are designed to show teachers possibilities. Then teachers are ready to

make a commitment to the possibilities of improving teaching and learning for their students.

The decision to implement the new technology needs to come from the teachers themselves; they are the ones who will be implementing the technology into classrooms and they are the ones who will be using the technology to improve teaching and learning. Although the classroom teacher knows that fundamental change happens in the classroom, the classroom teacher also knows that without the entire school adopting changes, the effort in the classroom will not be lasting without all department teachers making the same changes. The changes required for successful implementation will be permanent and the years of transition will be easier if all teachers in a department are engaged in implementation. The classroom teacher would tell you that administrative support and even community support are needed, but implementation plans should be documented so the plans can be publically shared with the administration and community. The most effective implementation plans would outline the rationale for involvement as well as requirements for involvement.

Equitable Student Access and Family Engagement.

If these classroom teachers were leading the implementation of technology innovation, the teacher would want each student to have access to the new technology. The teacher would want continuing and continual support time and resources from and for their fellow teachers. So a professional learning community (PLC) of fellow teachers should be cultivated and the time dedicated and protected. Those factors need administrative support, especially, the allocation of time. The administration must not

only allow, but lead the teachers to make the time available, and maybe most of all not violate the time that has been allocated. The administration must not only allow the focus, but support the focus by celebrating classroom innovation in technology in their school culture and allocation of fiscal resources.

If the classroom teacher were implementing a technology innovation that included students having the technology, the teacher would tell you the parents need to be told what the change is and why it is important. The change in the classroom is best conveyed by each teacher communicating with the students. If students are to come to school ready with their own devices, the communication needs to be done before the prior year ends. Some schools also communicate with students and parents through syllabus handouts sent home with students and some schools communicate through web sites where a significant change might be highlighted.

Collegial Support.

Teachers would tell you that support is the most important factor in the implementation. Support would be from fellow teachers as a formal or informal PLC. The group would meet regularly during protected, scheduled time. They would discuss activities that are to be tried in their classroom; they would create or find the activities in developed resources. After trying the activities in class, they would review the success, and the problems. They might bring in an online expert to help with the problems and to add breadth to their conversation. Online because having an outside expert would probably require more resources than available or divert resources that could be used in better ways. It would also respect the time resource from the outside expert in not

requiring travel to the location. It might mean that the outside experts might just be other teachers in another school who are meeting at the same time. They would discuss assessments that used the technology to emphasize the importance of the innovation to the administration, to the students and, through the students, to the parents. The PLC time would be protected. Protecting that time requires focus by the teachers and leadership by the administration.

Teachers discussed that useful any innovation that is going to change the practice and process in their classroom will take years. The first year is the introduction, the second year is the real implementation, the third year is the refinement, and maybe a fourth year is needed to really move the implementation from the status of an innovation to regular classroom practice. The facets of the technology teachers will use are dependent on the class being taught and the students they are teaching. Teachers need to become aware of the uses of technology in their content area and be able build from those uses to improved new uses arising from new technology.

Recommendations for Further Research

Presented here are suggestions for extensions of this research. This study focused on three classroom teachers who had been part of a planned implementation of a content-specific technology innovation. Each of these teachers evaluated themselves as successful enough to continue into a second year and had no intention of dropping the innovation. Were there any classroom teachers who began to implement this technology innovation and quit? What do they think about their experience? A future study would

be to obtain data from teachers who did not continue an innovation implementation and determine the causes of that decision.

This innovation was “an extension of graphing calculators” in the eyes of the teachers interviewed. Graphing calculators are widely used in this content area. What if the teachers interviewed were implementing a technology that was completely new? An example of that might be an interactive white board in a classroom where the teacher had not had any kind of computer projection available. Research on teachers’ level implementation of a uniquely new technology may yield different teacher needs and results from this study.

This study focused on classroom teachers in mathematics – a content area perceived as closely aligned to technology. Further research on what teachers in other content areas, especially those perceived as less closely aligned with technology, feel about implementations of technology in their classrooms would be useful. It would be beneficial to examine and document teachers’ feelings and thoughts since, as they said in their interviews, they are responsible for the implementation of the new technology.

Researcher’s Conclusion

Just half a century ago, the pace of implementing an innovation in three or four years might have been accepted without much thought. Today, the pace of technological advance does not seem to allow for multi-year implementations. As soon as year three is finished, the technology has been significantly changed and the process starts again. How do we solve that problem? Planning with recognition of challenges and being more specific about end results might help. The teachers participating in this study were not

part of the planning group, they were not given explicit goals or expectations, and they have not been taught to deal with the constant, rapid change that confronts them. Writing a plan with the teachers (or more generally, the implementers) that takes into account the factors they will experience would help.

Reallocation of resources of time, personnel, and funding will be necessary. If teachers are going to be continually confronted with change, they need time allocated and protected to implement that change. Not only do administrators need to allocate and protect time, but so do the teachers who are implementing. Resource personnel need to give up as much control to the innovators as possible and foresee some of the problems which may arise so they are ready to lend assistance. If resource personnel have too many other responsibilities or lack the specific expertise, then the system needs to be ready to hire specialists to assist and the local resource people need to be ready to give up control. Finally, the decision to adopt an innovation should be made with full knowledge of the resources needed to implement it. Those resources are represented by five research areas: school change, factors affecting the implementation of a technology innovation, how, why, and result of using technology in the content area, the developer's expectations and possible uses of the innovation, and, finally, the factors affecting the teacher who is the end user of the innovation in the classroom.

An implementation that takes years, includes the whole department, has the support of the administration and parents, and is using significant resources needs to be formal and written. It needs to be formative in nature so it can be amended as it matures over the years. It needs to detail each element and stage of the process so each teacher

understands the scope of the implementation and to commitments made by all parties to the project. The plan needs to have sections detailing which technology is important in the content area and why it is important in the content area; and then it needs to set expectations regarding how the new technology will improve learning.

If the adoption of the new technology is important to better teaching and learning, it needs to be a focus of the school improvement plan. It needs to have a time line so that none of the partners expects the implementation to go too fast or quits giving it supports before it is finished and is finally incorporated into the curriculum and accepted by the students and other teachers. And most of all, the long term implementation plan needs to recognize that teachers are in the classroom to teach students. That is their primary focus. The implementation needs to be planned to complement that focus.

The early introduction to the innovation may happen by reading or it may happen by attending conferences and workshops. Conferences are important for teachers to explore innovations and discuss their effects with other teachers. The initial professional development needs to be prior to attempting the implementation. The continuing professional development would be best accomplished within a professional learning community of implementing teachers, but with regular access to outside experts. The teachers must protect their ongoing professional development time as well as administrators protecting them from over scheduling. The purpose of implementing a content-specific technology innovation is to improve teaching and learning. Therefore, the professional development must include both training in how to functionally use the innovation and how to integrate the innovation into the teacher's curriculum.

Administrators should be open to face-to-face professional development, a PLC to assist and share, using outside experts through visits, coaching, and online interactive training. The training should continue throughout the implementation.

The implementation of content-specific technology is a team project. There is a position for administrators who desire that teaching and learning in their school and district be more productive and more efficient. There is a position for specialists within the district and within the academic field to assist the innovating group. There is a position for implementation assistance from outside commercial sources including the developer. The teacher implementer can then join the team as the major player on the team and the major contributor to the process.

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Appendix A: Expected Uses of the TI-Nspire

Summary of Possible Changes in Classroom Practice by Using TI-Nspire

Summary of Possible Changes in Classroom Practice by Using TI-Nspire suggested by Research on Graphing Calculators ¹ , SRI Review of TI-Nspire ² , TI-Nspire Web site ³	
1	Multiple representations in a problem ^{1,2,3}
2	Multiple representation on the same page ³
3	Multiple representations using different areas of mathematics ^{2,3}
4	Transformations of functions by “grab and move” ³
5	Transformations by changing the function parameters ³
6	Transformations by viewing multiple functions ^{1,3}
7	Explore families of functions
8	Linking variables in different areas of mathematics ^{2,3}
9	Linking variables between functions, tables, and graphs ^{2,3}
10	Viewing geometry figures interactively
11	Viewing geometry measurements interactively
12	Using the interactive geometry function to make conjectures about a property
13	Using the interactive geometry function as an integral part of a proof
14	Using a spreadsheet to investigate a connection between variables in a table
15	Describe data with a pie, bar, pictorial chart
16	Using a scatter plot to investigate if a relationship exists between two variables ^{1,2,3}
17	Using a scatter plot to find a linear function of best fit
18	Using a scatter plot to find a quadratic function of best fit
19	Using a scatter plot to find a function of best fit other than linear or quadratic
20	Collect data with science probes
21	Students save documents ^{2,3}
22	A saved document is used in class as a presentation to the class ^{2,3}
23	A teacher reviewing a saved document submitted by the student ^{2,3}
24	A student reviewing a document which was returned to the student after teacher review ^{2,3}
25	Using Connect to Class™ ^{2,3}
26	Student work is evaluated and adjustments to teaching result – student responses are used as a formative assessment ²
27	Teacher downloads (from the Internet) TI-Nspire documents for student use
28	Teacher develops TI-Nspire documents for student use
29	Students use documents developed by the teacher or downloaded from the Internet
30	Students develop problems and save them as TI-Nspire documents
31	Students engage in mathematics ^{2,3}
32	Students engage other students in learning mathematics ^{2,3}
33	Students communicate mathematics to other students ²
34	Students communicate mathematics to the teacher ²
35	Students use more time doing mathematics ²

36	Students reflect on mathematical concepts and/or ideas ²
37	Students find more support for difficult mathematics ²
38	Students use TI-Nspire as a calculator ¹
39	Writing about results of an investigation
40	Calculator programming
Summary of Possible Changes in Classroom Practice by Using TI-Nspire suggested by Research on Graphing Calculators ¹ or new functions of the TI-Nspire ²	
1	Linear equations ¹
2	Finding lines of best fit for data ¹
3	Systems of equations ¹
4	Absolute value equations ¹
5	Linear inequalities ¹
6	Quadratic equations ¹
7	Exponential equations ¹
8	Rational equations ¹
9	Non-functions ¹
10	Drawing or construction of lines and angles ²
11	Construction of triangles ²
12	Construction of polygons ²
13	Construction of circles ²
14	Conjectures about properties of lines and angles ²
15	Conjectures about properties of triangles ²
16	Conjectures about properties of polygons ²
17	Conjectures about properties of circles ²
18	Proofs of properties of lines and angles ²
19	Proofs of properties of triangles ²
20	Proofs of properties of polygons ²
21	Proofs of properties of circles ²
22	Vector representation ²
23	Vector addition ²
24	Spreadsheets used as lists ²
25	Spreadsheets used for calculation ²
26	Spreadsheets used to investigate the effects of changes to a parameter ²
27	Exploring families of functions
28	Collecting science data with handhelds
29	Graphing categorical data
30	Calculator Programming

Appendix B: Informed Consent Form

Title of Research Project: Teachers' Perspectives about Implementing a Technology Innovation

You are invited to participate in a research study of the implementation of a mathematics technology innovation in your school to help other teachers and administrators interested in adopting technology innovations. In addition, this study is being conducted to fulfill the requirements for a degree in Doctor of Philosophy. The study is conducted by Thomas S. Hibbs. Results will be used for dissertation completion. Thomas (Tom) Hibbs can be reached at 303-910-0750/tom.hibbs@du.edu. This project is supervised by the course instructor, Dr. Linda Brookhart, Department, University of Denver, and Denver, CO 80208, 303-871-2973 / email: Linda.Brookhart@du.edu.

Participation in this study should take about 180 minutes of your time or three 60-minute interviews. Participation will involve responding to open-ended questions about the implementation of the TI-Nspire in your classroom. Participation in this project is strictly voluntary. The risks associated with this project are minimal. Interviews will be audio taped. If, however, you experience discomfort you may discontinue the interview at any time. We respect your right to choose not to answer any questions that may make you feel uncomfortable. Refusal to participate or withdrawal from participation will involve no penalty or loss of benefits to which you are otherwise entitled.

Your responses will be identified by code number only and will be kept separate from information that could identify you. This is done to protect the confidentiality of your responses. Only the researcher will have access to your individual data. You will be able to review any excerpts taken from the interviews and work with the researcher to reword or remove excerpts you do not want included in the final report. However, should any information contained in this study be the subject of a court order or lawful subpoena, the University of Denver might not be able to avoid compliance with the order or subpoena. Although no questions in this interview address it, we are required by law to tell you that if information is revealed concerning suicide, homicide, or child abuse and neglect, it is required by law that this be reported to the proper authorities.

If you have any concerns or complaints about how you were treated during the interview, please contact Susan Sadler, Chair, Institutional Review Board for the Protection of Human Subjects, at 303-871-3454, or Sylk Sotto-Santiago, Office of Research and Sponsored Programs at 303-871-4052 or write to either at the University of Denver, Office of Research and Sponsored Programs, 2199 S. University Blvd., Denver, CO 80208-2121.

You may keep this page for your records. Please sign the next page if you understand and agree to the above. If you do not understand any part of the above statement, please ask the researcher any questions you have.

I have read and understood the foregoing descriptions of this research project. I have asked for and received a satisfactory explanation of any language that I did not fully understand. I agree to participate in this study, and I understand that I may withdraw my consent at any time. I have received a copy of this consent form.

Signature _____ Date _____

I agree to be audio taped.
 I do not agree to be audio taped.

Signature _____ Date _____

Thank you so much for your interest in this study.

Appendix C: Interview Guide

Research Question: What were the classroom teachers' perceptions of their level of use after the adoption of a technology innovation and what factors influenced them to achieve that level of use?

First Interview

Introduce the project and tell what to expect. Explain purpose for the research, what I am attempting to learn, and how research will be used and shared. Tell a little about my interest in the project. Tell how I got their name and why I selected them to participate. Explain the interview process, why it is being recorded, what to expect in each session, etc.

Informed Consent

Review in detail the Informed Consent form and ask them to sign a copy. Give them a copy of the form for their records.

Opening questions to help frame the discussion to follow:

Question Interview 1: "In 2008 your department decided to adopt the TI-Nspire as a math technology to replace the graphing calculator. You participated in the implementation of TI-Nspire in your classes. Tell me your story as it relates to that particular innovation."

From the resulting narratives look for effects and ask follow up questions, related to implementation of the TI-Nspire in the narrator's classroom. If the researcher needs to help the classroom teacher with questions, choose some from below:

Ask about key points from the teacher, for example, "You mentioned that you use the TI-Nspire. Tell me a little about that. What has been driving your implementation?"

Ask, "Tell me what you have been doing to learn more about using your TI-Nspire. Do you share your use with other teachers? Do you feel isolated in your use of the TI-Nspire or does it seem to be a department project? Why do you feel that way? What has determined your sharing?"

Ask, "What is the atmosphere in the classroom when students are using the TI-Nspire? How is it affecting your teaching and students' learning?"

As time allows, ask for examples or stories, feelings about or reactions to the experience, and changes the participant brought.

At the end of the interview, explain that next time you will explore some of these areas more deeply. Ask the teacher to make a note of anything that comes up in the time between the interviews that might be of interest.

Tell them, "I'm going to try to excerpt some of your more salient thoughts and put them in frameworks of school change, technology implementation, teaching and learning, and

functional use of the TI-Nspire. You will get a chance to look at my analysis and we will review it together to make sure it tells your story accurately.

Second Interview Guide

Interview 2 opening question: “This research is your story told in your words. Would you look at the excerpts from the first interview and the connections I’ve found with frameworks of school change, technology implementation, teaching and learning, and functional use of the TI-Nspire? This gives you as the narrator a chance to see that your first interview was accurately understood. Do you feel I have accurately portrayed your thoughts? Expand on any of these themes that seem most important to your implementation of the TI-Nspire in your classroom.”

From the resulting narratives look for effects and ask follow up questions, related to implementation of the TI-Nspire in the narrator’s classroom. If the researcher needs to help the classroom teacher with questions, choose some from below:

Ask, “I’ve marked items you touched on from the research framework that encompasses school change. Were any of the other aspects listed on your “Connections” graphic from “school change” part of your consideration in this implementation? Please take time to explain.

Ask, “I’ve marked items you touched on from the research framework that encompasses implementation of a technology innovation. Were any of the other aspects listed on your “Connections” graphic from “technology innovation” part of your consideration? Again, please take time to explain.

Ask, “As a math teacher, you are probably most familiar with the research framework that encompasses the use of technology in teaching and learning mathematics. I’ve marked items you touched on from that framework. Were any of the other aspects listed on your “Connections” graphic from “technology in mathematics teaching and learning” part of your consideration? Please take time to explain.

Ask, “The school and the district purchased new technology. I’ve marked the items you touched on from the framework of functional use of the technology. Were any of the other aspects listed on your “Connections” graphic from “functional use” part of your implementation and how did those factors affect your implementation?”

Third Interview Guide

Interview 3 opening question: “We’ve had a chance now for you to relate your story about the implementation of the TI-Nspire into your classroom, to review and recommend changes in my interpretation of your narration, and to review research

frameworks for school change, technology implementation, technology impact in the content area, and functional use of the specific technology. Summarize your thoughts and feelings about the factors that both enabled and hindered your implementation?”

Appendix D: Interview Summary Form

Analysis of teachers' perception of their degree of implementation and the factors that affected that degree of implementation.

Teacher Ref. Code: ____ Today's Date: _____

Interview Number: ____

1. Main patterns and themes that became apparent during the interview.
2. Information that relates to the research question(s).
3. Particularly salient stories on back.

Perception of Factors Influencing Degree of Implementation for Change of Practice:
Perception of Factors Influencing Level of Innovation-specific Use:
Perception of Factors Influencing Level of Content-specific Use:
Perception of Factors in Design of the Implementation to Maximize Successful Change in Teaching and Learning:
Perception of Level of use:

Appendix E: Data Analysis Organizer

	Teacher 1	Teacher 2	Teacher 3
Relevant Instances of Words:			
Common Theme:			

Adapted from a form used by C. Mears (2009). Interviewing for education and social science research: The gateway approach.