7-2009

Diverging Perspectives: A School District's Response to and Instructional Support Application

Sarah Crose
University of Nebraska-Lincoln, sarahlcrose@gmail.com

Diverging Perspectives: A School District's Response To An Instructional Support Application

by

Sarah L. Crose

A DISSERTATION

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Doctor of Philosophy

Major: Educational Studies

Under the Supervision of Professor David Fowler

Lincoln, Nebraska

July, 2009

Diverging Perspectives: A School District's Response To An Instructional Support Application

Sarah L. Crose, Ph.D.

University of Nebraska, 2009

Advisor: David Fowler

The purpose of this descriptive qualitative study is to better understand how teachers and district leaders respond when implementing a technology instructional support application. The study also explores the influences affecting that implementation process. Secondary mathematics teachers who had been presented with the option to implement a web-based instructional software were interviewed to understand their perception of the implementation process. District leaders were interviewed to understand district philosophies and policies influencing technology decision making within the district.

Findings of this study indicate that teachers are willing to invest time toward the implementation of a web based application if given adequate support along with an application that supports student learning by utilizing both mastery learning and reduction of cognitive load. The presence of a champion for the application and strong interest from the district offices impact how successfully teachers are able to implement an instructional application. This study suggests that teachers, district leaders, and the champion of the innovation being implemented have distinct perspectives and attitudes. Implications of this study point to the need for additional quantitative and qualitative research exploring how teachers choose to use technology and how that use affects student learning.

Dedication

To my husband and my parents.

Acknowledgements

My multi-year journey toward a doctoral degree is nearing its end. Without the encouragement, guidance, and help from many other people, I most likely would not be at this point. I have appreciated the practical guidance of my advisor Dr. David Fowler. He has patiently listened, thoughtfully responded to my questions, and helped me discern my research path. I have also appreciated the support, encouragement, gentle prodding, or affirmations of my supervisory committee.

I attribute my desire to continue learning through out my life to my mother. She modeled an active quest and value of education and lifelong learning during her life. Even in the years after her death, I have felt her subtle encouragement to continue on in my academic education.

The stars of this paper are all the participants who graciously agreed to be a part of my research. I appreciate the time that each of the teachers gave to me as I gathered data for this study. Without their candid sharing of experiences and perceptions, this study would not have been possible. These teachers are the heartbeat of this study.

Friends, colleagues, and family have encouraged me along the way. I am thankful for their words of support. They have encouraged and cheered me on to completion. I am deeply appreciative of the editing support that I received from my sister Mary and my colleagues Sue and Debbie.

I am especially grateful for the support that my husband, John, has given me. His constant encouragement to *get it done* has kept my goal alive. He has had faith that I could get it finished even when I felt overwhelmed. He has been my rock throughout this journey.

Table of Contents

List of Tables

List of Figures

List of Appendices

Chapter 1

Introduction

A story was relayed to me about a young boy receiving a flint and steel from his grandfather. Knowing that outdoorsmen would use these tools to build a fire, the boy was excited to try his hand performing that task. He gathered some dry tinder into a pile and struck the flint and steel together. A spark fell into the tinder. The boy blew upon the tinder, but the spark grew cold and went out. He continued to strike the flint and steel together and then gently blew upon the spark and tinder to give it oxygen. Each time he hoped for a flame to appear. After trying many times to no avail, the young boy lost interest, packed up his flint and steel and put them away. Later the boy had the opportunity to observe an expert demonstrating how to start a fire using a flint and steel. He observed that the expert would strike the flint and steel many times in rapid succession. This produced a shower of sparks that fell into the dry tinder. It was the production of many sparks and oxygen that ended up producing a smoldering in the tinder. As an appropriate amount of oxygen was supplied, it grew to be a small fire.

Flint and steel serve as a metaphor for the way a new idea is birthed and given life within an education setting. Sparks of curiosity and interest are often produced by demonstration of a new technique, resource, tool, or technology at a conference or a convention. However those new sparks of curiosity and interest will die out unless there is some continuing source feeding the spark.

Education is a continuously evolving field. Throughout the history of education in the United States, educators have been asked to embrace new ideas and strategies for teaching. In the last 15 years alone, a search of articles written concerning teachers and change yielded 926 titles. Often, after only a few years of emphasis on a new idea, the current idea fades from importance as a "newer" or improved idea takes its place.

Having experienced the ebb and flow of ideas, educators are skeptical of the longevity of their efforts and involvement. It is not uncommon for a teacher to remark, "This, too, will pass." Given the pressures put upon teachers to implement the "newest" educational fad, why would a teacher voluntarily learn to use and implement a new innovation when it is not a requirement of their district? Why would a teacher willingly invest time given past experiences with the fickleness of change in education? What is the motivation for teachers to embrace the implementation of an optional new educational technology?

Purpose

In 1996 a mathematics faculty member of a large mid-western university developed a software program that provides instructors with a flexible means for placing student practice and assessment online. The original program was created as a means for providing practice and assessment for calculus students. Currently, instructors representing a wide cross-section of disciplines across the university campus are actively using the program. This same software program was made available to a public school district located near the university. Secondary math teachers had been invited to learn how to use the program and then implement it into their classroom teaching.

The purpose of this study was to examine how teachers incorporated a new technological tool into their teaching practices as well as their perceptions about how the program had impacted their teaching. This study attempted to describe how teachers voluntarily agreed to use a new program in their teaching and how the district's response to the implementation of the technology impacted the implementation.

Background

Acting upon his math chair's conviction that testing student's basic skills using the web could enhance the university's calculus program, a mathematics professor at a large mid-western university designed and developed a software program to be used in the calculus courses. In November 1996, the university's math department version of the software was first run. By 1998 the first commercial version of the software was offered by publisher John Wiley who branded it Wiley Web Tests in Calculus. Wiley realized that the software program was of benefit to calculus students and should be offered to other universities for use in their calculus classes.

The very first program was written in CGI programs using C. However in 1997, the original developer realized that a new programming language, Java, would provide more flexibility for the program. Java allows for objects to be placed into the program. The entire software was rewritten using Java as early as 1997. The university developers believed that this testing software should be promoted as a tool not only usable for calculus courses but also for use in other disciplines desiring online assessments.

In subsequent editions, Wiley Web Tests second edition in 1999 and Wiley e-Grade in 2000, the program appeared as a multi-disciplinary software. After 2000, development of the program was moved to Brownstone Learning. Brownstone Learning re-branded the software with its current name, EDU. Brownstone Learning's focus was to get the software out to as many disciplines as possible. Brownstone, in collaboration with the mid-western university professor, continued to develop the software from 2001 to 2004.

Around 2003 another software company, Maplesoft, became connected to Brownstone Learning and EDU. They eventually developed their own version of EDU, branding it Maplesoft TA. Both EDU and Maplesoft TA are very similar programs, but are developed by two different companies.

Early on in the development of EDU, the idea of not only making the software available to a variety of disciplines but also making it available to the local K-12 district was put forward. University individuals approached a teacher from the local school district concerning the potential availability of this new software program. The possibility of using the program with pre-collegiate students became of great interest to both parties. Being the sole owner at the time, the university math professor offered the local school district a free unlimited license for the use of his software program. It was agreed that the university would host the server for the program until the time the school district desired to take control of the management of the server or until the public district's expanded use of the program would become problematic for the university server. This agreement has been continued to the present time. Currently EDU is an optional instructional support application for the local district teachers to use with their students.

In the spring of 2005, the local public school district teacher observed a remedial high school math class where EDU was used on a weekly basis. He observed student success when EDU was in use. His observation indicated that high school students, who had struggled to meet their math requirement for graduation, were very successful after practicing required skills using EDU in mastery mode. Approximately 39% of the students had passed the Math Graduation Demonstration Exam (MGDE) at end of the first semester prior to the use of EDU. During the second semester, students used EDU on a weekly basis. Approximately 89% of the students passed the MGDE at the end of that semester.

During the summers of 2004 and 2005, grant funds were available to hire one of the district math teachers to write problems for the software program's question banks. These problems would become a base set of problems to be used in the district's EDU high school and middle school course question banks covering Algebra and eighth grade math. This completed set of questions paved the way for secondary math teachers in the district to more widely use the software program.

Ultimately, optional staff development courses that were organized and offered to all secondary mathematics teachers prior to the start of the 2005-2006 school year. The one-and-a-half hour staff development courses provided an opportunity for teachers to learn the basics of managing the EDU program. EDU building web sites were set up for the teachers that attended the staff development sessions. The EDU sites were complete with the question banks that had been previously written. The local teacher who was the catalyst to initiate EDU offered whatever help was needed to assist these pioneer classroom teachers in getting the EDU program up and running in their classrooms. He offered to come directly to the buildings to provide further teaching on EDU details and to prepare course specific question banks for the teachers to use. Teachers were free to incorporate EDU as they saw fit in their classrooms and lessons.

Seventh and eighth grade teachers at several middle schools used EDU fairly extensively during that year. Some teachers used EDU as a means for preparing for quizzes and tests; others used it primarily as a re-teaching tool for students who did not master test objectives.

The teacher promoting EDU retired at the end of the 2005-2006 school year. The following year, 2006-2007, teachers were left to find help on their own and to be more innovative in their management of the actual EDU program. At the time of this study no other leader within the district has yet emerged to provide guidance and assistance for teachers who have chosen to incorporate this software into their classrooms. Recently the university announced that their campus would be migrating to a program that has evolved from the original EDU program. The university's decision to migrate to this program and not continue supporting the original EDU program may be a looming hurdle for district teachers who currently use EDU.

Description of EDU Program

EDU is a user-friendly program, which provides a rich and varied format for teachers to create problems, assignments, and assessments facilitated through the Internet via the institution's server. Each instructor is able to manage their own Class Homepage by creating question banks and assignments unique to their class. Instructors are able to create questions using a variety of formats: text, mathematical, and interactive.

Figure 1. Sample EDU class assignment page.

The program, originally written for calculus problems, recognizes algorithms. This is an important feature for the mathematics teacher because algorithms allow the question creator to structure a question coupled with a range of values for the variable(s) in the problem. EDU can then provide unique problems each time the algorithm is presented to a student. Feedback to students on their progress is most beneficial when the feedback accompanies the problem being assessed (Clark & Mayer, 2003). EDU allows feedback to be written so that students are able to examine their own work compared to the suggested solution to the problem.

Once question banks are created, the instructor is able create assignments by selecting individual questions or groups of questions to be placed in the desired assignment. A variety of tasks can be selected for each assignment. Mastery is one task that can be selected for a particular assignment. When in mastery mode, a new question is produced for each that is incorrectly answered until the student has correctly answered a prescribed number of questions. Assignments can also be written as a test or quiz. Depending on the security level desired by the instructor, a proctor login requirement can be set for assignments in test or quiz. Assignments have the flexibility to be scored or to be for practice only. Even flash card type assignments can be created. Instructors can regulate the length of time that an assignment is available to students. If practice is the primary goal, an assignment can be set for an unlimited number of student attempts. Likewise, the amount of time can be restricted should the instructor desire a quiz to be only available for a limited time.

Math Intervention Classes

The local public school district has tried various means to help students who are struggling to fill in the gaps and become successful in their particular on-grade-level mathematics class. Middle school was targeted as the key instructional level where some type of intervention needed to occur in order to better prepare these students high school mathematics courses including Algebra. Algebra is the gateway math course for students aspiring to go on to college (Riley, 1997). Research has shown that students who take Algebra in the eighth grade are more likely to advance on to college than students who do not take Algebra until ninth grade (Gamoran & Hannigan, 2000; Riley, 1997).

The district had tried grouping students with lower ability in a homogenous adjusted math course. This course presented lower ability students with a modified curriculum. However, concern arose over the limited scope of mathematics to which these students were exposed. The district decided to abolish the adjusted math classes and currently places all middle level students in heterogeneous on-grade-level mathematics classes. An additional intervention mathematics class is scheduled for those students who exhibit a deficiency in mathematics achievement as evidenced on a standardized math test, class progress, or by teacher recommendation. The purpose of the intervention class is to support the student's regular on-grade-level math class by pre-teaching or re-teaching lessons covered in the regular education class. Students who in previous years would have been in a limited exposure adjusted math class are now working their way through a rigorous on-grade-level class with the support of the intervention class.

Problem Statement

Research has shown that spending 15 minutes preparing for homework on a web-based application improves homework performance (Garbin, Bradley, & Mason, 2002). Spending 40 minutes in a web-based activity can save up to ninety minutes or more of lab time, time that can be devoted to critical thinking exercises. Additionally the use of web-based exercises proved to be a strong remedial tool for correcting errors in prior assignments. These results indicate that using a web-based program with post-secondary students not only increases student learning and mastery but also saves valuable educational time that can be utilized for deeper learning exercises. Liu, PytlikZillig, and Brunning (2005) reported that collegiate students have a generally positive attitude when working assignments on a web-based application. They also noted that students seemed to gain confidence toward taking tests and using the computer.

Such results at the collegiate level could transfer to the secondary level of education, grades 7-12. EDU appears to be a promising tool for classroom teachers to use when aspiring to help students achieve mastery over selected mathematics objectives and as a tool to maximize teaching in the mathematics classroom.

The Diffusion of Innovations Theory (Rogers, 2003) cites five stages in the process to adopt and implement an innovation: knowledge, persuasion, decision, implementation, and confirmation. This study used Roger's theory as a basis for understanding the needs and perceptions of teachers as they advanced from knowledge of a new technological innovation through the implementation stage in their classrooms. The needs of a teacher as he or she engages in choosing how to implement a new innovation received special focus.

Research Questions

Grand Tour Question

How does a district respond to the opportunity to introduce a web-based instructional support application?

Multiple points of view increase the understanding about how a new technology is adopted and implemented in an educational setting. Interviews were conducted to explore these viewpoints.

Sub-questions

1. How do teachers describe the process of incorporating a new technology software program into their teaching?
2. How do teachers learn or develop the core knowledge needed for implementing a new technology?
3. How do teachers perceive their learning process when implementing a new technology program?

4. How do teachers perceive the impact of the new software program on their teaching?
5. How do district consultants describe the process of incorporating new technology software programs into the district?

Data Gathering Method

Case study was used to examine the experiences and perceptions of teachers as they implemented a new technology. The choice to use case study as a research instrument provided a means for exploring the thoughts and actions of teachers as they worked through the implementation of a new technology. This qualitative case study focused on secondary level math teachers who had the opportunity to implement EDU in their classrooms. Interviews were conducted with teachers who were exposed to EDU staff development sessions and either decided for or against the implementation of EDU. District consultants were interviewed to get the wider district viewpoint on technology implementation.

Definition of Terms

Brownstone Learning – founded in 2001. Co-ownership of Orr's program renaming it EDU Campus

C – A computer programming language.

CGI– Common Gateway Interface, an interface with program servers for external gateway programs. This interface allows for dynamic outputting of information, not just static form.

Champion – A leader or advocate for an innovation.

EDU – a software program originally developed by John Orr, Ph. D., mathematics professor University of Nebraska, Lincoln.

Foundations in Math – math course for last year high school students still needing to meet the district's graduation requirements for Mathematics.

Java – an object oriented programming language.

Math Intervention (MI) – additional remedial class for middle school students.

MGDE – Mathematics Graduation Demonstration Exam.

MPS – Midplains Public Schools, a large urban school district in a midwestern, city.

On-grade-level – Describes a course that matches content with a specific grade (i.e. seventh grade curriculum for seventh grade students).

Assumptions

This study assumes that the teachers participating in the study were voluntary participants and had the freedom of choice in their involvement in the implementation of EDU. It is also assumed that the teachers in this study are representative of those who have a functional comfort level with technology.

Delimitations

A delimitation of this study is that the case centered on secondary mathematics teachers from one unique school district. Because of the uniqueness of this district, city, and state, the findings are not necessarily representative of all secondary mathematics teachers.

Limitations

This study was limited to the secondary mathematics teachers of one urban mid-western public school district. This study was also limited to teachers' perceptions of the implementation of one specific software called EDU.

Significance

There have been strong criticisms of teachers underutilizing technology to transform their teaching practices (Cuban, 2001; Oppenheimer, 2003). This case study increases our knowledge concerning the adoption and implementation of new technology. Understanding how secondary school mathematics teachers learn to use a new technology, adapt it to their classroom, and provide the support needed during that implementation could be of value to curriculum leaders who are interested in providing effective practice and assessment tools to teachers. Examining the difficulties and successes experienced by teachers, and how teachers perceive the program's usability and effectiveness may provide valuable information for educational leaders and teacher groups as they plan for implementation of new educational innovations in the future.

Chapter 2

Review of the Literature

Historical Perspective

Nationally, schools in the United States have been experiencing a long and steady trend toward more students taking algebra a year earlier in the eighth grade rather than the traditional offering of algebra in ninth grade. Coupled with that trend toward algebra as an eighth grade course is the inclusion of algebraic concepts in all of the elementary grades. A brief look at events during the 20th century will help in understanding why there has been a shift from algebra being offered solely in high school to algebra being available as a course in the middle school curriculum and for algebraic concepts being taught to students as young as first grade.

Shirley (2000) notes that even though people have been learning mathematics for hundreds of years in the United States the formal study of mathematics as an academic field began in the first decade of the 20th-century. It was not long after the turn of the century that the National Council of Teachers of Mathematics (NCTM) was founded in 1920. The purpose of NCTM was to organize mathematical education. Throughout the 20th-century educators have sought to strengthen curricular content and to improve instructional strategies in the mathematical field.

By the 1950’s and 1960’s the focus of mathematics educators turned toward a deeper understanding of mathematical ideas. This focus on understanding mathematical ideas gave birth to curriculum revisions dubbed “New Math.” Although the ideas in the “New Math” were good, many thought that rigor and abstract thought were over emphasized causing the progress of the “New Math” curriculum to be slowed.

While the birth of “New Math” was a pivotal point in turning the focus of mathematics teachers to mathematical ideas rather than exclusively focusing on the teaching of mechanics and problem solving, perhaps the biggest influence on United States mathematics education occurred in the early 1980’s. Reports, such as A Nation at Risk (Goldberg & Harvey, 1983), declaring the low achievement of United States students brought intense concern over the state of mathematics education. In 1989, NCTM published Curriculum and Evaluation Standards for School Mathematics. Soon to follow were companion publications Professional Standards (NCTM, 1991) and Assessment Standards (1995). In 2000 NCTM published Principles and Standards for School Mathematics, which serves as a guide for mathematics education in this 21st century.

The ground swell of the last 20 plus years has lead to a greater shift toward algebra being not only introduced in the earliest years of a student’s education but also in the number of students now encouraged or required to take algebra by their eighth grade year of school.

The 1995 Third International Mathematics and Science Study (National Center for Educational Statistics, 1995) punctuated the fact that United States students did not perform as high on math and science assessments as did students in other industrialized countries such as Germany and Japan. Concern for the ability of the United States to be able to compete with other countries in a highly technical future was heightened. It was apparent that more of our students needed to have a strong mathematics background to enable them to pursue highly technical careers. The ability for students to go on to college and potentially select a mathematical or science field is predicated on their taking a rigorous high school course of study in mathematics (Riley, 1997; Gamoran & Hannigan, 2000). “Algebra is the ‘gateway’ to advanced mathematics and science in high school, yet most students do not take it in middle school” (Riley, 1997, p. 5). Enabling students to complete the gateway course of algebra in middle school set up the path for students to pursue a rigorous mathematical study in high school.

In the late 1800’s and first half of the 20th century, the most common pattern of schooling only required students to attend through the eighth grade. High school was not mandatory, thus many students did not attend school after the eighth grade or if they did go on to high school they did not graduate. Those attending high school were a more select group of academically capable students and only the students who scored well on entry-level mathematics classes were allowed to take higher-level courses (Romberg, 1992). In the last half of the 20th century the attendance requirement for schools was raised to 16 or 18 years of age. This rule changed the clientele of secondary schools from that of college bound, middle class youth to all persons up to age 16 or 18 (Romberg, 1992). A new challenge for mathematics educators emerged concerning how and what type of mathematics courses should be available to students with a wide range of ability. One answer to addressing the wide range of ability was to create tracks where students would either be on the college track or the non-college track. In most schools, fewer mathematics and science courses were available to lower-track students (Oakes, Gamoran, & Page, 1992). Once tracked it was very difficult for students to shift to the college track if so desired. If a student is not exposed to higher more rigorous mathematics courses, their ability of pursuing careers needing mathematics is greatly hampered.

Equity for all students, then, is also at the forefront of this evolution in United States mathematics education. An alarming fact was raised by Riley (1997) that students of low-income and minority status were rarely represented in the ranks of those students who excelled in the math and science fields. Algebra has been considered the gateway course that allows access to the rest of high school math-offerings. As a result focus has been directed on not only getting more students of all economic and ethnic backgrounds to take algebra in high school but also on students taking it a year early in eighth grade (Gamoran & Hannigan, 2000; Ma, 2005; Smith, 1996; Starr, 2003).

> Early access to algebra has a sustained positive effect on students, leading to more exposure to advanced mathematics curriculum and, in turn higher mathematics performance by the end of high school. Students who entered high school with algebra already on their transcripts continued to take academic mathematics courses. These students stayed in the mathematics pipeline longer and advanced farther than their contemporaries who took algebra in high school. (Smith, 1996, p. 148)

The United States middle level math curriculum has been identified as a probable weak link in the United States education system (Riley, 1997). Smith (1996) notes that the National Center of Education Statistics (NCES) as early as 1994 found that effective middle schools had eighth grade students taking algebra rather than general mathematics. As one example of reducing tracking, about five years ago the Midplains Public Schools school system eliminated a middle level math course adjusted for struggling, low-achieving math students and began placing all students in an on-grade-level course or higher. The result is more students being exposed to algebraic concepts and potentially preparing them to take algebra in eighth grade. Taking algebra a year early is an important factor in protecting students from being tracked and becoming *stuck* in an academic pattern which prevents them from taking more rigorous courses in high school.

There are, of course, advantages and concerns surrounding early entry to algebra. Advantages include allaying the fear of algebra that arises when taken in high school, allowing students to take more demanding math and science courses in high school, and providing time and background needed for taking a wide variety of higher-level high school courses. Concerns include the fear that early focus on algebra will be at the expense of other necessary math skills and concepts, fears that early introduction to algebra will be so rigorous that students will be turned off to math, fears that the quality of teaching in the middle school will not meet high school standards (Starr, 2003).

Despite the concerns on the part of some, the shift for algebra to be a more prominent middle school math course seems to be only gaining speed. While some feared that algebra offered to lower-achieving students would be watered-down, this proved to not be the case (Gamoran & Hannigan, 2000). Having more academically diverse students in the algebra classroom raised a fear that great numbers of students would fail. Gamoran and Hannigan (2000) cite a case where when one school district's percentage of students taking algebra increased from 59% to 90%. The passing rate during the same growth period actually increased from 56% to 74%. The approximate 25% failure rate in this school district was a point of concern, however it was much lower than in previous years. The district indicated that more students were taking algebra and passing the course than ever before. If this school is an indication of what is to come, the future looks strong for algebra to truly become a course for all students to take and perhaps take a year early in middle school.

Technology in Education

Critics in education have opined that the introduction of massive amounts of computers to schools and classrooms across the United States has been an unsuccessful experiment. Promoters of wide scale use of computers in classrooms hoped to bring about fundamental change in instructional practices. Seymour Papert, MIT, is quoted as saying in 1983; "There won't be schools in the future. I think the computer will blow up the school. That is, the school defined as something where there are classes, teachers running exams, people structured in groups by age, following a curriculum – all of that" (Oppenheimer, 2003, p. 20). Critics claim that monies toward further implementation are a poor investment (Cuban, 2001; Oppenheimer, 2003). Indeed changing the way teachers teach in classrooms throughout the U.S. has not occurred as dramatically as Papert predicted.

Cuban (2001) observes that although computers are indeed abundant the use of those computers during direct instruction is not evident in most teachers' presentation. Cuban makes clear his concern about continuing the tremendous expense of putting more and more computers in the classroom if those machines will not be used in innovative and instructional changing ways on a frequent basis.

Both Oppenheimer (2003) and Cuban (2001) make a clear distinction between the use of computers by teachers and students during actual instruction and their use outside of instruction for preparation and management. While Cuban's message primarily is one of cost effectiveness, Oppenheimer is concerned that even when computers are used extensively that there is not a gain in student learning. He concludes that too much time is spent on computer activities that do not require deep thinking and analysis.

Despite the cautions of Cuban, Stoll, and Oppenheimer, the National Council of Teachers of Mathematics (NCTM) posits that technology is important for teaching and learning mathematics effectively.

> Technology is an essential tool for learning mathematics in the 21st century, and all schools must ensure that all their students have access to technology. Effective teachers maximize the potential of technology to develop students' understanding, stimulate their interest, and increase their proficiency in mathematics. When technology is used strategically, it can provide access to mathematics for all students. (NCTM, 2008, ¶ 2).

Mathematics teachers have been charged with the responsibility of utilizing the power of new technology to advance student understanding and mastery of concepts. Echoing Oppenheimer's concern that deep thinking and analysis not be sacrificed when using technology, NCTM (2003) states that teachers must be prepared to serve as knowledgeable decision makers in determining when and how their students can use these tools most effectively.

New technologies such as computers, calculators, interactive white boards, digital cameras and projectors, visual presenters, and personal digital assistants (PDA's) have a dramatic influence, if not fundamental change, on the way that teachers prepare to teach, deliver instruction, assess learning, and manage a menagerie of daily tasks. Teachers have embraced technological devices as an integral component of their daily routines and have begun to use them more and more during the course of their instructional time with their students.

Technology and Cognitive Load

Educational computer programs are most effective when issues of cognitive load are acknowledged and implemented. Learning is most efficient when individuals allocate all of their cognitive resources to essential learning. Few or none of their cognitive resources should be focused on incidental learning or the holding information to be referenced later. If this is not accomplished the result is cognitive overload. Three primary causes of cognitive overload are: processing too much information simultaneously, an overload of a combination of both essential and incidental information, and the necessity of holding in memory information while engaged in another task (Bruning, Schraw, Norby, & Ronning, 2004). Computer programs can avoid cognitive overload by heeding six principles described by Clark and Mayer (2003). The multimedia principle relates to the use of words and graphics together rather than just words alone. The contingency principle advises placing in close proximity those words and the graphics they explain. The modality principle allows for both sight and hearing modalities to be accessed by using audio in place of written text if the learner is required to study a diagram, chart, or picture. Redundancy in using both audio and text for the same purpose is ill advised. It is better to use audio alone or text alone rather than read passages of text that are placed on the screen. The coherency principle addresses the concept that more is not necessarily better when it comes to adding interesting but extraneous graphic or audio details. Finally the personalization principle encourages the use of a conversational style in delivery and a virtual coach or pedagogical advisor if possible.

In computer programs it is important to not have connecting information on independent pages. This is especially true when giving feedback to a student response. A space near the student response should be provided so that corrective feedback can be placed near the response and the original question. Students need to be able to see the problem, response, and feedback at the same time in order that the link between feedback, response, and question is easily made. Using highlighting to designate the correct response also enables the learner to identify the appropriateness of their response. “Thus when the learner answers a question, he or she should see four components on the screen: directions, question, response, and feedback” (Clark & Mayer, 2003, p. 165). Using an expert’s paraphrase as feedback to learners is an effective strategy (Morrison, Ross, & Kemp, 2001).

Technology: A Slow Revolution

Authors Cuban (2001), Stoll (1995), and Oppenheimer (2003) offer little hope that widespread use of new technology to transform instructional practices will ever occur. Papert’s prediction concerning how instruction would change has not materialized since the massive push for computers in the classroom started in the 1980’s. One of Stoll’s (1995) laments concerned the inability to effectively carry out e-commerce online. It is of interest that was the same year eBay was created and three years later PayPal entered the cyber scene. In the ten years since Stoll’s’ book was published in1995, the apparent impossibility of completing financial transactions efficiently and securely online has become a reality. That monumental change indicates that we are indeed most likely on a slow-revolution of technological change.

Just as time is needed for advancements in the delivery of technological services, time is also needed for the educational organism to master the delivery of technological benefits to the classroom. Over and over Oppenheimer (2003) found that teachers were reluctant to utilize technology fully in the classroom. When he asked teachers to identify a reason for that reluctance they repeatedly said it was a lack of training.

Most teachers are now very capable in their personal use of computers. Students of today are astute users of a wide variety of technology. This is the next generation of technology savvy educators. The time has come when technological entrepreneurs who have skillfully integrated technology into their classroom practices will be called upon to provide quality in-service for the next wave of techno-usage in instruction.

Feedback

In an interview with *Educational Leadership*, Bloom stated,

> In every country of the world children's achievement is normally distributed when conventional group instruction is used. If on the other hand each child is taught by a very good tutor, all will learn to a high standard with very little variation, although some may take slightly more time than others. (Bloom, 1979, p. 157)

One-on-one tutoring is expensive and not feasible when teaching large groups of learners in a school system. The question is how to achieve one-on-tutoring in a group setting. Bloom identified utilizing the feedback-corrective process as most important (Bloom, 1979).

Feedback related to a learner's performance guides the learner to reject incorrect or inefficient problem steps, nudges the learner toward correct procedures, and confirms when the learner is on the right track. "We assert that successful instruction nearly always includes performance-related feedback. From our perspective, improving the quality and quantity of this form of feedback is requisite to improving student learning" (Brooks, Schraw, & Crippen, 2005, p. 641). Providing answers to a completed test or assignment, discussing solutions with peers, and computer-assisted instruction (CAI) are all examples of how feedback can be delivered to the learner. "The most effective CAI consists of having students respond to problems and receive feedback about those responses" (Brooks et al., 2005, p. 642).

One study compared two groups of students both of which received enhancement teaching on missing prerequisites for learning a lesson. One group additionally received feedback concerning what they did not know accompanied by a prescription on how to learn it. The group receiving feedback performed significantly higher than the group with pre-teaching alone (Senemoglu, 2001). The type of feedback is also important. Feedback that only informs a learner if they are correct or incorrect is not as beneficial as feedback that includes an explanation (Moreno, 2004).

Mastery Learning and Technology

Mastery increasingly will be a desired outcome for all learners. The No Child Left Behind Act of 2001 (Public Law 107-110) has increased the stakes of mastery. The No Child Left Behind Act (NCLB) holds schools accountable for seeing that students, annually, meet proficiency requirements called annual yearly progress (AYP). "The purpose of AYP is to ensure that 'all schools' and 'all students' meet the same academic standards in reading and mathematics by the 2013-2014 academic year" (Kim & Sunderman, 2005, p. 3).

Nearly all students are able to achieve at a high level if they are provided an appropriate learning environment. This belief is the hallmark of teaching for mastery. Mastery Learning (ML) refers to instructional methods that facilitate students gaining a proficient level of achievement over set criteria. Benjamin Bloom, recognized for formulating the mastery model theory, predicted that by using mastery learning 95% of students could reach a high level of mastery that previously only 5% would reach when mastery learning was not employed (Motamedi & Sumrall, 2000).

John Carroll (1963) described a model of mastery learning where the degree of learning is a function of the ratio of the amount of time spent learning to the amount of time needed. “In common parlance, it is the time during which he is ‘paying attention’ and ‘trying to learn’” (Carroll, 1963). Two general methods of mastery learning strategies have been explored. Individualized instruction meets the needs of the individual learner at the point he has difficultly learning the required information. The learner does not move on to the next lesson until he has proven proficiency on the current lesson. Group instruction focuses on teaching a group of students. If some students do not achieve proficiency remediation is provided prior to moving the group on to the next lesson (Kulik, Kulik, & Bangert-Drowns, 1990).

According to Bloom (1979) the feedback-corrective process it is the most important component to ML. The learner practices a concept and then receives corrective feedback at the end of the practice. If the learner is proficient, she will move onward in a straight-line learning path. If the learner is not proficient, then he or she will be directed to other types of practice to hopefully help him or her achieve proficiency. “Mastery approaches to learning can yield greater student interest in and more positive attitudes toward the topics learned. Mastery approaches can also generate in students increased confidence in their ability to learn” (Block, 1973, p. 34).

Mastery learning is most effective when students have a clear description of the mastery process. Ritchie and Thorkildsen (1994) found that students who were informed that they were involved in a mastery learning process performed at a higher academic level than those who were not informed of the process. The informed process involved understanding how a student's performance would affect their path through the learning materials. Understanding how performance determines progress through learning materials prompts a student to set goals for investing the appropriate amount of time needed for that student's learning. "This knowledge may alter their perception of control over the learning environment, that altered perception, in turn, may alter their attention to the learning environment" (Ritchie & Thorkildsen, 1994, p. 89).

Mastery of mathematical skills is a goal that school districts, teachers, and parents desire for the students in their charge. Without sufficient practice and feedback, mastery of mathematics objectives can be difficult for most students. An early drawback for use of ML had been the dramatic increase in teacher workload to create the multiple practices and tests as well as the volume of record keeping needed to manage ML. Fortunately with technological advances in the classroom multiple practices and tests can be created by computer software. Currently software is available that is capable of easing a teacher's previous burden of providing adequate practice repetitions, determining mastery, and maintaining detailed student records. Computer programs can generate a vast number of unique problems using a common format. Computer programs can provide learners with opportunities to study at times and paces suited to the learner's needs. Teachers can utilize computer grade books and record keeping programs for evaluating students' performance. "Mastery learning and computer assisted instruction provide a perfect match as schools become more reliant on technology" (Motamedi & Sumrall, 2000, p. 35).

Slavin (1987) describes a teacher's dilemma of meeting the learning speed of all learners as the "Robin Hood" effect. Under traditional learning environments time is taken from students who need more time to learn so that the faster learners can progress or time is taken from the faster learners so that the students needing more time can receive re-teaching.

> Computers can aid mastery learning in the following three ways: (1) many students need additional time and individualized practice with feedback to meet objectives. Computer programs can often provide opportunities to study at the times and pace suited to the individual's needs. (2) Additional programs can be made available for students who master objectives quickly. (3) Computerized grade books and other recordkeeping programs can help teachers keep track of student performance. (Vockel, & Mihail, 1993, p. 40)

Diffusion Theory

"Diffusion is the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 2003, p. 35). Social systems move through a process of innovation-diffusion before ultimately deciding to adopt or reject the innovation. Rogers (2003) described this process as consisting of five stages: knowledge, persuasion, decision, implementation, and confirmation. In brief an individual or group gains knowledge of an innovation and becomes persuaded through various means to either make a decision to adopt or reject the use of the innovation. If the decision is to adopt, then there is a period of implementing the innovation which culminates in the individual's or group's confirming whether the decision to adopt was appropriate or not.

Awareness or knowledge of an innovation may be a passive or aggressive activity. Knowledge of an innovation may be gained via communication with individuals already aware of the innovation. Knowledge might be actively sought out because of a need within the social system. “A need is a state of dissatisfaction or frustration that occurs when an individual’s desires outweigh the individual’s actualities. An individual may develop a need when he or she learns that an innovation exists” (Rogers, 2003, p. 172).

Persuasion may result in either a favorable or unfavorable attitude toward an innovation. During this process the individual is mentally processing and interpreting information to predict if the innovation will be advantageous or disadvantageous in a specific situation. The persuasion stage results in a decision to either adopt or reject the innovation.

The implementation stage is where the real test of the innovation occurs. The individual learns how to get, use, and solve problems stemming from the learning process and application of the innovation. “Problems of implementation are usually more serious when the adopter is an organization rather than an individual” (Rogers, 2003, p. 179). The persons implementing the innovation may not be the ones making the decisions to adopt the innovation. “The organizational structure that gives stability and continuity to an organization may resist the implementation of an innovation” (Rogers, 2003, p. 179). Modification or re-invention of the innovation may also occur during the implementation stage. It is of interest how much if any re-invention occurs.

After a season of implementing the innovation the individual or social system will reevaluate whether to continue adoption or to cease the decision to utilize the innovation. If the benefits are sufficient for continuing then the innovation will be melded into the normal routines and the individual may also become an active promoter of the innovation (Rogers, 2003).

Chapter 3

Methodology

Research Design – Case Study

Curiosity causes people to step aside and take a closer look at something of interest. This curiosity when taken up by the researcher becomes a method for seeking a larger understanding of a unique phenomenon (Stake, 1995). Case study allows the researcher to examine, in a deep way, the thoughts, ideas, and perceptions of individuals. Examining ordinary events in a natural setting is a strength of qualitative studies. As a result "we have a handle on what real life is like" (Miles & Huberman, 1994, p. 10). It is important to give an accurate description and voice to practicing teachers as they relate their experiences concerning the process of implementing new innovations.

This case study is intrinsic in that it sought to describe and understand how teachers implement a specific technology (EDU). The case is unique. However, "people can learn much that is general from single cases" (Stake, 1995, p. 85). The use of case study has produced a rich description about how teachers have voluntarily agreed to implement a new technological program within their teaching and their perception of the ensuing impact to their teaching.

Population and Sample

The population for this study was composed of secondary math teachers in a large urban mid-western school district who had experience with the use of EDU in their classrooms and teaching. Teachers were selected out of a pool of high school and middle school teachers who attended staff development sessions or training on the use of EDU. Other persons of interest were individuals who have been instrumental in creating EDU, individuals who encouraged its use in the public school setting, and consultants from the school district. This study was bounded by the experiences of the individual teachers.

Research Questions

Grand Tour Question

How does a district respond to the opportunity to introduce a web-based instructional support application?

Multiple points of view increase the understanding about how a new technology is adopted and implemented in an educational setting. Interviews were conducted to explore these viewpoints.

Sub-questions

1. How do teachers describe the process of incorporating a new technology software program into their teaching?
2. How do teachers learn or develop the core knowledge needed for implementing a new technology?
3. How do teachers perceive their learning process when implementing a new technology program?
4. How do teachers perceive the impact of the new software program on their teaching?
5. How do the district consultants describe the process of incorporating a new technology software program into the district?

Role of the Researcher

"Standard qualitative designs call for the persons most responsible for interpretations to be in the field, making observations, exercising subjective judgment, analyzing and synthesizing" (Stake, 1995, p. 41). The role of the researcher in this case study was to exercise those charges. As interviewer, the researcher was the data collection instrument in the field. Data was collected through a series of interviews and was transcribed verbatim. The researcher separated the data into key elements by the use of coding and domain analysis. Finally, salient themes were sought that described the case.

Interview Protocol

Each participant was asked to sign an informed consent form. Several face-to-face interviews were conducted with some follow-up queries via telephone or e-mail correspondence. "A short list of issue-oriented questions" (Stake, 1995, p. 65) that allows participants to freely describe their experiences and perceptions were used to gather data. Interviews were structured to focus on specific phases of the implementation process: formation, implementation, and confirmation. Audio recordings of each interview were taken and then transcribed.

Confidentiality of the participants was guarded in several ways. The researcher transcribed the audio recordings of each participant interview. Each audio recording was erased after the transcriptions were completed. All copies of the written transcripts will be kept for a period of two years in a locked case in the primary researcher's residence. At the end of that time period the documents will be destroyed. Anonymity of the participants was assured by the use of pseudonyms and by generalizing identifying characteristics.

Validity

Misunderstandings, misrepresentations, and inaccuracies must be guarded against as much as is possible. “We assume the meaning of an observation is one thing, but additional observations give us grounds for revising our interpretation” (Stake, 1995, p. 110). Triangulation of data helps protect the validity of the qualitative case study. Triangulation was accomplished in several ways. Data was gathered from multiple sources and at different times. In addition the utilization of member checks helped to assure internal validity. Participants, or members, were provided the opportunity to review and confirm the accuracy of information pertaining to their interview. Peer researchers were invited to review the research in order to maintain validity and clarity.

As a mathematics teacher in the urban mid-western school district, the researcher had an interest in how other mathematics teachers implement technology in their classrooms. The researcher being a teacher in the district had opportunity to work with the software being studied. These connections to the study could contribute some bias to the study. However the primary role of the researcher was that of data gatherer and inquirer. Additionally, the researcher did not hold any supervisory authority over any of the participants. The researcher was interested in the perceptions and perspectives of other teachers not her own. Finally, no responses were used in any way that would jeopardize the participant’s standing in the district.

Chapter 4

Analysis

Midplains Public Schools (MPS) is a large urban public school district in a mid-western city that is also home to a major university. The district educates more than 34,000 students from Kindergarten to twelfth grade. Students in kindergarten through fifth grade, attend school at 1 of 36 elementary schools. Ten middle school buildings house students in grades six to eight. The district's six high schools are comprised of ninth to twelfth grade students.

The district refers to teachers teaching in grades seven to twelve as their secondary teaching staff. The secondary teaching staff includes teachers of all curriculum areas. One of the core curriculum departments is the mathematics department. At the time of the study there were 130 secondary classroom mathematics teachers. These teachers taught courses ranging from on-grade-level seventh grade mathematics to advanced mathematics courses such as AP Calculus.

In order to graduate from this district a student must take two years of high school level mathematics, which includes taking first year Algebra. Passing a Mathematics Graduation Demonstration Exam (MGDE) has been an alternate way to meet the math requirement. Currently the District is phasing out the MGDE as a way to meet the graduation requirement for math and is requiring students pass two years of high school math. Algebra must be one of the classes successfully taken.

The District consistently works to provide avenues for struggling students to meet the math graduation requirements. In recent years teachers have been asked to provide multiple ways for students to succeed in mathematics. In the middle schools, students who demonstrate that they have large gaps in their math skills are placed into an additional math class that meets either every day or every other day depending on the grade level in which the student is enrolled. These Math Intervention classes are designed to be a support to the student's regular math class and to address the gaps in the student's learning. The goal is for all students to be as prepared for high school Algebra as possible.

For high school students, the District provides courses in Algebra designed for students who did not pass their Algebra class. The courses for *repeater Algebra*, as teachers of this course describe it, are often scheduled for a continuous two class period block of time. An additional course is also offered to students who have not met either of the two criteria for meeting their math requirement by their final year of high school. This *last chance* math course is called Foundations.

Mastery of a course's objectives is desired for all students. Mastery has generally been identified as attaining a score of 80% or better on the test over a particular objective. For students not achieving mastery, it is expected that teachers offer opportunities where these students are able to re-learn and re-test any unmastered objective.

The District as a whole has a wide acceptance for instructional technology. Buildings have common computer labs that teachers may reserve for their classes. Often there are one or more computers in classrooms that are available for teacher and student use. Productivity based software, such as Microsoft Office, is available on all district computers. School buildings are wired to receive the Internet. Wireless connections are available for teachers using laptop computers. Often there is an unequal balance of technology available in specific buildings due to the aggressiveness of building technology liaisons or curricular liaisons. Some teaching teams are recipients of technology grants. Technology within the district spans a diverse range of hardware such as computers, smart boards, projectors, and document cameras.

Scientific calculators are available for students in all secondary math classes. Extensive use of the scientific or graphing calculators is mostly evident in advanced mathematics courses such as Statistics or Calculus. There is no prescribed district wide mathematics software except for the software program required by the high school Statistics class. As would be expected, math teachers in this district vary widely in their use of technology and their comfort level with technology use.

Technology has widely been used in schools to increase productivity such as word processing and researching the Internet. As researcher, I was interested in the response of a school district when met with the opportunity to implement an Internet based instructional support software program. This web-based software program had the potential to not only increase teacher productivity but also promised to be a benefit to student learning,

My goal was to better understand factors that influence how a school district responds to the opportunity to embrace and use a new technological instructional support application. To learn more about this phenomenon, one particular case was chosen to study. MPS is a district that was presented with such an opportunity. This qualitative study concerns a unique case that is bounded by one urban public school system and the secondary math teachers teaching in that district. Other district officials were sought out to give insight on district philosophy and guidelines concerning the adoption of new technologies within the district.

Champion for the Innovation

Mr. Fleming

Mr. Fleming saw the rise of the computer era in the local public school system during his 39 years with the MPS district. He taught math at the beginning and end of his career at one of the high schools but more than half of his teaching career was in the technology (IT) department at the district office. He describes himself as committed to K–12 education. Mr. Fleming's tenure in the IT department began with the purchase of the district's first ten Apple II E computers. That purchase was followed by the purchase of some Commodore 64's, Radio Shack Trash 80's and experimentation with some smaller computers. Mr. Fleming continued with the IT department until two years before his retirement. As a member of the district's IT department, he saw the rise of technology in education and its infusion into the school system.

Late in his tenure with the district IT department, Mr. Fleming became aware that the university had a supplement to their math courses. That supplement was called variously Gateway tests, e-Grade, and ultimately EDU. Shortly there after, he learned of a workshop at the university that was given for the university faculty on the use of EDU. It was at this workshop that Mr. Fleming became acquainted with the EDU software. He recalls that a follow-up meeting with the software's creator, Dr. Orr, resulted in EDU being made available to the MPS school system. Mr. Fleming gives full credit to Dr. Orr as being the stimulus for EDU to be made available to secondary school classes.

Mr. Fleming states, "But it could not have happened other than to go through Orr and Orr being advocate and champion for us. And he always has been. He's been very, very giving of his time."

Mr. Fleming grew more interested in discovering how EDU might look and work in the secondary school setting. As a result of his curiosity, training on EDU was offered primarily to volunteer teachers who also were interested in seeing how it might fit with their assigned courses. He describes training as primarily coming from three sources. The university provided training, Dr. Orr directly trained individuals or small groups of teachers, and Mr. Fleming conducted training sessions. Mr. Fleming and other teachers were experimenting with EDU during the three years prior to Fleming's effort to bring EDU into common usage in secondary math classroom. They were learning how to write questions for the question banks. Some teachers actively wrote problems for the question banks that aligned to particular grade/course level objective cards. Mr. Fleming understood that a barrier to successful teacher use was the availability of ready-to-use question banks.

A workshop led by the creator of EDU, was conducted for Mr. Fleming and the other math teachers who were learning how to create questions for the question banks in EDU. They were able to fine tune their skills and find answers to specific problematic areas. One problem was finding the best Internet browser to use when working with EDU. The browser Safari did not work very well with the EDU program. Using that browser created a problem with editing some types of problems. At the workshop the teachers were able to gain insight from Orr concerning how to overcome such difficulties.

The school year prior to Mr. Fleming's retirement, he saw that all interested secondary math teachers were given opportunities to attend workshops that acquainted them with the EDU program. Mr. Fleming recalled,

> They had chances for workshops, periodic, not regular, but there were opportunities. It was acquainting them with the test banks that were available. How they worked and trying to give them a vision for how it could work. And then it was, if you need, if you're interested and want more you can call. Then we can get serious and make it work at your place.

A systematic plan for training sessions was not necessarily in place. However during this particular year Mr. Fleming made himself available to any group of teachers that desired to know more about using EDU. Mr. Fleming compares his investment of time to the overhead a business invests in setting up shop. Mr. Fleming notes, "Every system like that has an overhead. You have to get to first base before you can use it. If you go with any system like this, it does require that initial investment. And that's not a weakness of EDU, but rather that comes with any system like that."

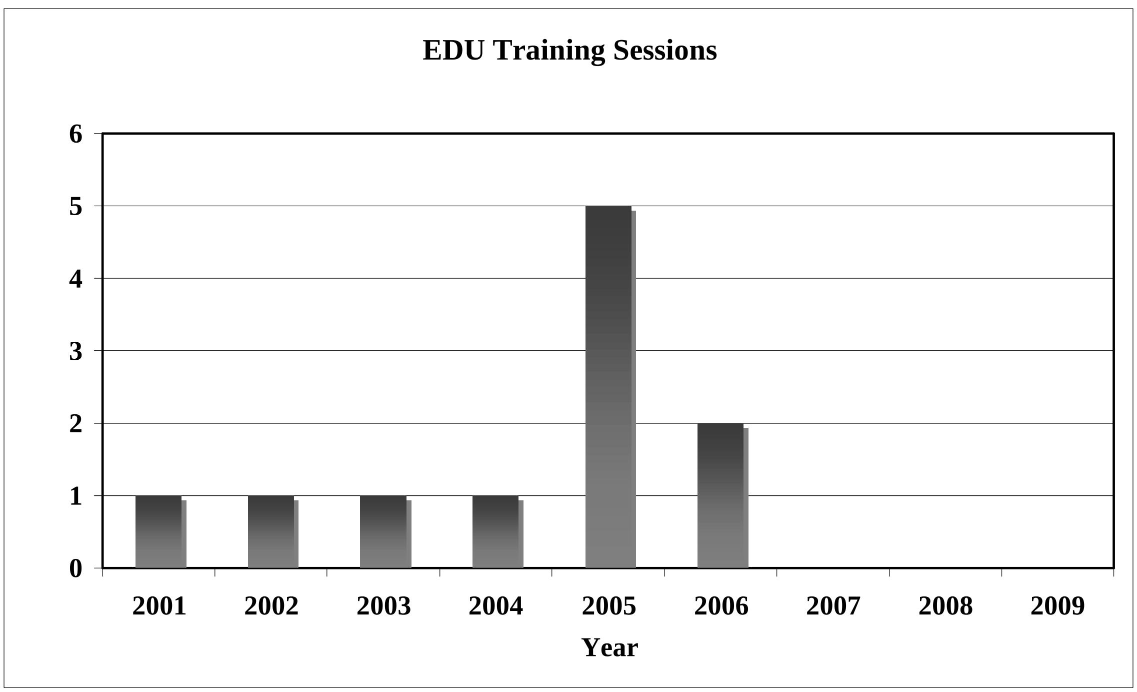


Figure 2. Estimated number of EDU training sessions.

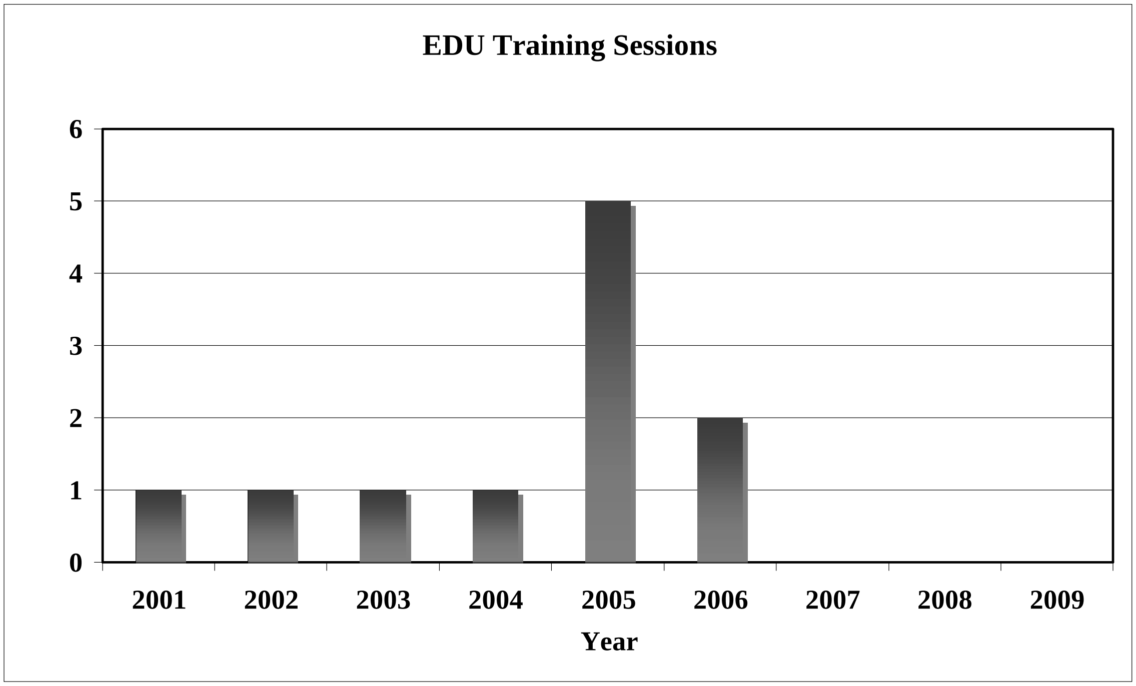


Figure 3. Estimated attendance at EDU training sessions.

Mr. Fleming's experience in the IT department gave him ample vision for seeing the vast potential for computer use in schools. "I thought more and more computers are coming into schools. Teachers are becoming better acquainted with them, that I thought EDU [*sic*] could have a huge potential." In describing EDU's potential, Mr. Fleming said,

> I thought the fact that it was computerized would be another intervention that would help kids, especially low-achieving kids, become a little bit more motivated maybe. Well, it was worth the initial investment to conduct an experiment. And the experiment was the first classes that would go in and use it. So we didn't invest much up front. The initial investment, an initial visit to the computer lab and observations then, immediately suggested that it was worth it.

Mr. Fleming initially believed that EDU's greatest potential was for high school Algebra students who did not have the prerequisite skills needed to be successful in Algebra. "That's where I saw the barren waste land in high school math. There were so many kids coming to the high school that were not all prepared for Algebra. They didn't have the pre-requisite skills and they were being placed in Algebra." Mr. Fleming realized that with EDU, Algebra problems could be broken down to fundamental components and students could practice enough fundamental problems to gain mastery over the fundamentals prior to working problems with variables.

Mr. Fleming recognized EDU's ability to provide instant feedback as a benefit for student learning. Mr. Fleming observed,

> I also saw, early, the potential of the feedback that it could have. I always felt that the university never, and higher Ed in general never tapped into the feedback like they could. We understood that better than all of higher Ed that uses it. And we spent twice a much time on the feedback as we did on the questions. Because to show every step of the solution took time, but we felt it was worth it.

EDU's ability to randomly provide problems to students so that no two students receive the same problem is also a strength that helps to engage students.

Mr. Fleming commented on how he assisted early users of EDU in the start-up process,

> Two surprises in EDU: 1.) Kids in the right environment – and the right environment was me and another teacher in the lab. 2.) I was there especially early to make sure everything worked. Just to take all the computer problems away from the teacher. I assumed all responsibility and for getting the kids oriented. That was the deal I make with the teachers.

Mr. Fleming also worked the room, helping students remember that when a problem was missed that another problem would be given for extra practice.

> So we'd prime the group and say, 'Well you're going to get another one. Take a look at how you missed this problem, see how the problem is worked because it's coming back and you're going to have to know how to do it.' It was amazing.

Mr. Fleming carefully observed student interaction with the computer generated question. Early on in the experimentation with EDU, he and other teacher question writers decided to move away from multiple-choice problems. Instead they chose to focus on questions with free response answers. Mr. Fleming noted that when some of the students were presented with multiple-choice problems their behavior revealed that

> they were gaming the system because if another one is coming immediately back, I'll just fire four of these up and I'll get one of those four right and I've got it. Then we can go to the next one. So if it's a ten-problem exercise I just have to hit the A or B forty times and I'm out. Now it wasn't quite as blatant as what I'm stating, but there was that tinge to it and we caught it early on.

In order to not make obtaining correct answers overwhelming, problems were purposefully broken down into fundamental parts so that students were able to master a more complex problem by mastering smaller steps within the problem.

Mr. Fleming realized EDU could be used in any curricular area. For example a sixth grade teacher used the software program with her Spelling curriculum. Mr. Fleming helped this teacher set up the EDU program for this unique use of the software.

> She would talk into a microphone and say, "Dog. The dog ran across the street." Then on the screen you would see "The _______ ran across the street." You would have to type in the word "dog." Then on the screen you could hit the button and it would play the sentence and repeat the word.

Even though there are more and more computers in the district's schools, those computers are concentrated in computer labs. In order to have an entire class doing work on computers the general purpose labs have to be scheduled. Mr. Fleming noted the school's attempt to achieve equitable use of labs by all teachers,

> I think schools do a very poor job of prioritizing instructional interventions for use in their computer labs. In education, one thing that is commendable about education is equity. But equity is interpreted in schools as everybody is equal or everybody deserves equal access.

In the end, that may not be the best use of the computer technology. Mr. Fleming asserts that computer labs should be prioritized so that interventions with evidence of producing positive results have a greater access than interventions that do not prove to produce student benefit.

Lack of active support by the district for software such as EDU is likely to hinder its spread in the district. Mr. Fleming asserted that without district support it would be difficult for teachers to continue using the software. He predicted that few if any staff development opportunities would be offered. His prediction was proven to be accurate. After the flurry of workshops offered during the promotional year, no other workshops have been offered since Mr. Fleming's retirement. The champion retires, the district does not actively support the innovation, and training comes to a halt.

Mr. Fleming sited the importance of a champion or lack thereof to the successful implementation of the EDU software program in secondary classrooms. "You know, you always have to ask, 'Who's the champion?' If there isn't a champion, it's probably not going to happen. It's not easy for it to happen."

According to Mr. Fleming, the creator of EDU willingly gave of his time to visit with Fleming and other math teachers about technical points of concern which arose through their use of EDU and the writing problems for EDU. Mr. Fleming described Dr. Orr as an advocate and champion for the MPS teachers. He comments, "And he always has been. He's been very, very giving of his time. I would phone him up and ask questions. I've gone to his office and he's always been very accommodating."

In the same manner in which Dr. Orr was a champion for Mr. Fleming, in reality Mr. Fleming was the champion for promoting and training district staff members in the use of EDU. He hosted workshops as a catalyst for teachers to begin use of EDU in their classrooms. He willingly worked with small groups of teachers to deepen their understanding of how to tweak questions to meet the needs of their students.

Mr. Fleming's initial awareness and interest in EDU began while he was working in the district's IT department. By the time Fleming began his efforts to widely disperse knowledge of EDU throughout the district's math teaching staff, he was back in a leadership position at one of the high schools. The champion for EDU in essence worked from the bottom up, or at the grassroots level, in order to initiate implementation of this web-based software program.

Championship from the district level was very limited. Mr. Fleming observed that the district department tended not to champion new ideas that were not produced from that office or were promoted from the top down. While they did not necessarily block the promotion of EDU, resources were not allocated toward it other than sponsoring workshops that would serve to fulfill district requirements for staff development hours. The district funded the cost for any staff development workshop presenters.

As champion of an innovation, Mr. Fleming could see the value of investing time as it related to the future. Mr. Fleming relates what occurred at one middle school,

> They were doing very good things. They had a male eighth grade math teacher. He was doing after-school remediation in the computer lab with EDU. He got it. He understood it. He was using it. He was the champion at the school [*sic*]. He leaves, it falls flat on its face. Because he understood it well enough that he could make things happen. Ah, and it wasn't a stressor to him. Yeah, it takes your time, no doubt about it. But you can do it. You understand it. You know where it's going. That's what's needed.

Mr. Fleming's hope was that the district would eventually see the value of EDU or a similar product. He perceived that EDU would be an investment that could affect a teacher and his or her students for the life of that teacher's career. Mr. Fleming, while a champion for what software such as EDU could bring to education, did not advocate

EDU as the only option for the district. He acknowledged that he would be thrilled if the district office saw the value of EDU and decided that they wanted to support a product similar to EDU. His biggest fear would be that if the district did choose different software that it would be a "lesser product" when compared to the EDU software and not be as useful to teachers or students. Mr. Fleming's investment in EDU in essence was an investment toward the potential for EDU, or similar software, to become a vital component in the public school.

Mr. Fleming had championed other "innovations" during his career in teaching. Early in his career, he promoted the use of end of course tests. He felt these tests should be accompanied by testing periods long enough to accommodate the tests. Teachers could validate what students were or were not learning. At the time the idea did not receive favor but as years have progressed that idea has become the norm in MPS high schools. Mr. Fleming also recognized the need to gather real time information to guide teaching. "One of my goals was before you leave school at the end of the year, you're going to know what the kids did poorly on and we're going to have a game plan for the next year on what we're going to teach better."

Mr. Fleming observed a particular student who was a member of an Algebra-Extended class. This mathematics class spread a one-year course out over a two-year time period. He acknowledged the challenge for teachers when working with students who have learned quite well how to avoid the current task at hand during math class. Mr. Fleming described observations of a student named Frank on two separate days,

> Frank fiddled [*sic*] his way around the whole class period I was observing. He was the ultimate con artist. He gets his backpack out and he does this and there's a water bottle and there's this and there's the cute girl next to him. Everyone knows him. He's a friend of everybody in the world. So I cajoled him. I challenge

> him and say, uh, let's get to work. And he'd say, "Yeah, I got to get my book. It's in my back pack." He spends the whole period and he doesn't do anything, absolutely nothing. But yet, if you were looking there; you really wouldn't know he wasn't doing anything. I mean he is just good at surviving and not doing anything. I chewed him out. I kind of cajoled him. I humored him. Nothing worked, absolutely nothing. The next day we go to the computer lab, EDU. He works thirty-five problems correctly. I know because it's in the grade book and I observed him. The previous day, nothing, zip, absolutely zero and he was kind of a pain in everybody's side. You know, a distraction, the class clown. I think that's why you need a variety. So I think EDU can have that potential to do it.

Mr. Fleming noted that all parties involved in student academic direction did not always view success in the same way. EDU was being used during the second semester of a course designed for twelfth-grade students who had not yet met the math graduation requirement. Students enrolled in this course were allowed to take a graduation demonstration exam at the end of each semester to determine if they met the district's standard for graduation. At the end of the first semester only 39% of the students passed the exam. EDU was used at least once a week to supplement the regular class sessions. Remarkably at the end of the second semester 89% of the students enrolled in this course were able to pass the exam. Unfortunately instead of celebrating the success demonstrated by the use of EDU, Mr. Fleming and the teacher of the course were cautioned that the students had an unfair advantage because their practice was so much like the official exam. Mr. Fleming noted that all EDU problems entered into the EDU question bank, came directly from the district's own practice publications that were available for use in studying for the exam. EDU software randomly selected values to create different problems each time a student practices on the computer. Mr. Fleming described the EDU problems as modeling the format of each practice problem. "Everything we did in EDU was generalized. We used random numbers to change the problems." Mr. Fleming and the teacher who wrote the question bank problems purposefully chose district practice problems to use as the model for all EDU problems.

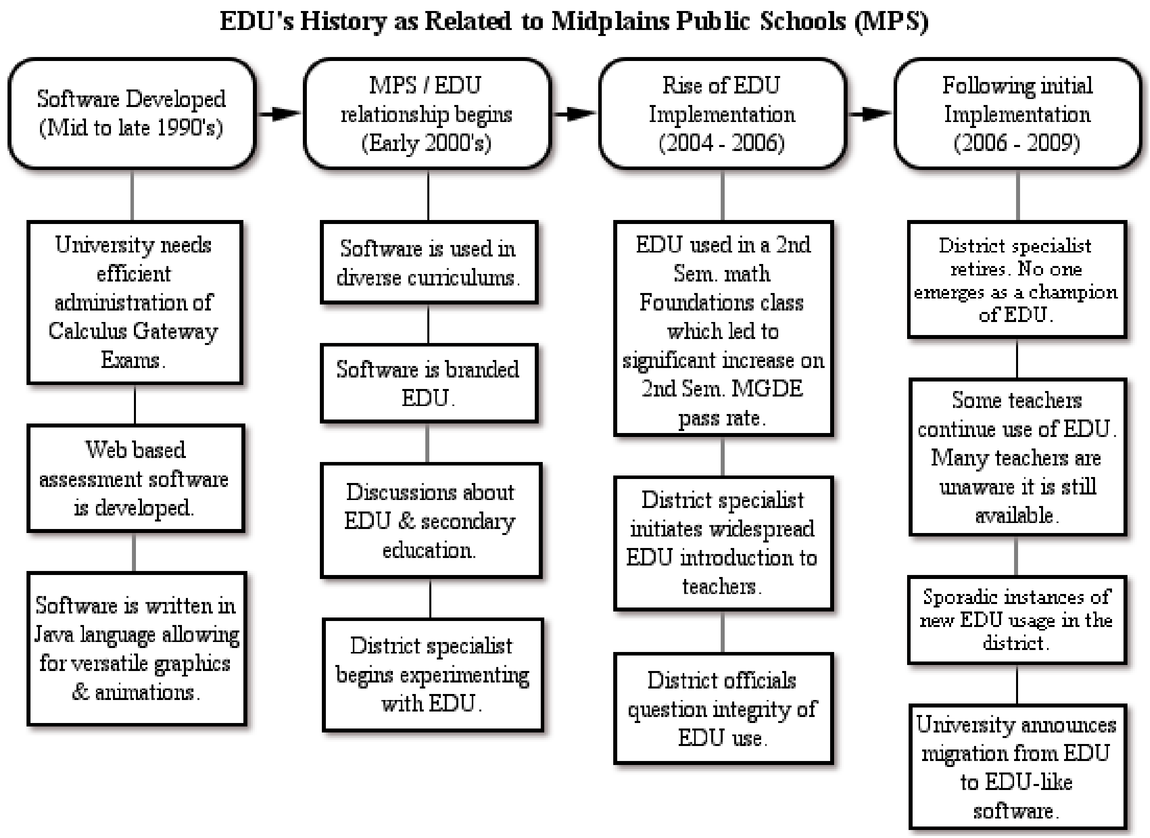


Figure 4. EDU's history as related to Midplains Public Schools (MPS).

Introduction of Teacher Participants

I began my search for potential teacher participants by mailing a survey to each secondary math teacher who was teaching in the district. In addition to demographic information, the survey asked the responding teacher to note their experience with the software being implemented called EDU. More than 60% of the math teachers responded to the survey. Out of the responders, over a third of the teachers (37%) indicated that they had some experience with EDU. Teachers with EDU exposure were grouped into one of five expertise levels based on their years of experience working with EDU. Experience levels (years) ranged from *very experienced* (>3 years), *experienced* (3 years), *moderately experienced* (2 years), *limited experience* (1 year), and *very limited experience* (<1 year).

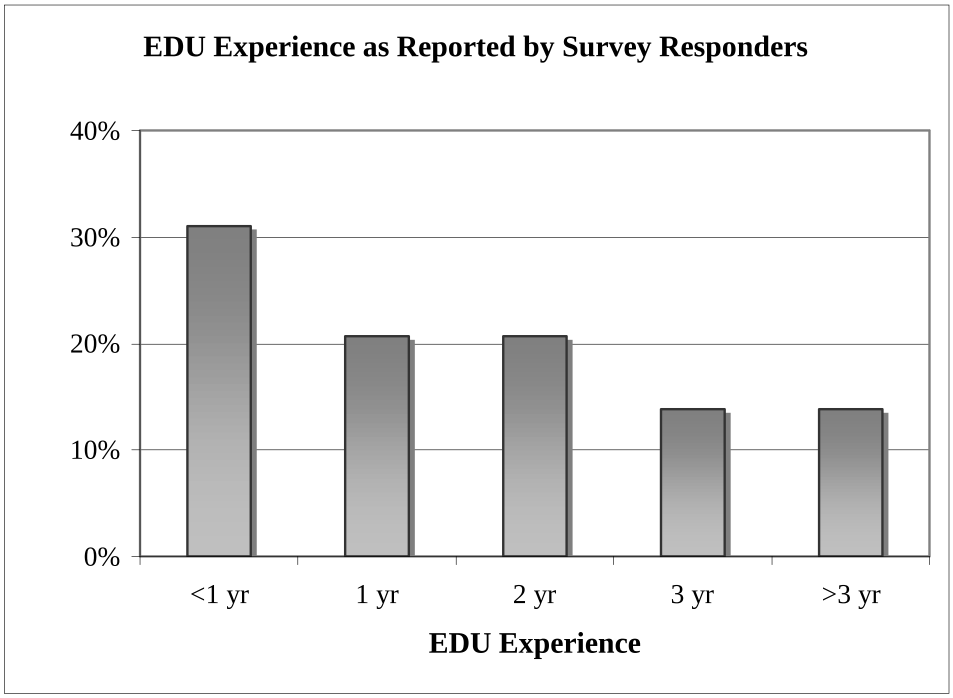


Figure 5. Responder EDU experience.

Six teachers were randomly selected based on their experience level with EDU. Each was invited to be a part of this case study. The participants' experience level of working with EDU in the classroom ranged from *very experienced* to *very limited experience*. One of the participants was from the very experienced group, representing those teachers with more than three years of experience. Two participants were selected from teachers who had two to three years of experience working with EDU. Two participants had one or less years of experience. One of the six participants had attended a staff development session on EDU but ultimately did not choose to use EDU in the classroom.

Each participant was required to sign an Informed Consent Document. The participants were assigned a pseudonym. Participants are referred to by their pseudonym throughout this paper. Three participants were male and three were female.

At the time of the study, the participants had an average of 11.7 years of teaching experience. An average of 9.2 years of their experience had been with the MPS district. An assumption of this study was that participants, teachers who had experienced EDU, would have some comfort with the use of technology. One of the participants admitted to being very adept, even gifted, at the use of technology. However, most were modest in describing their comfort or use of technology. None of the participants were novices as far as being able to use basic productivity programs on the computer. All were able to use the computer to communicate via email, create and save documents or worksheets, and browse the Internet. Each of the participants had attempted to use technology in their classroom in some capacity.

Mr. Loflin

Mr. Loflin was a high school math teacher who primarily taught various Geometry courses. He had a B.S. in Mathematics and had been teaching for nine years. Five of those years had been in the MPS district. Mr. Loflin described himself as a person having low comfort with technology. However he acknowledged that most of what he did as far as preparing and saving teaching materials was done electronically. He had become comfortable with a software program called Geometer’s Sketchpad®. Mr. Loflin used that program with his students in class. Mr. Loflin also described himself as, “I am kind of old school I guess.”

Mr. Loflin learned about EDU nearly two years prior to Mr. Fleming’s district wide staff development opportunities. However Mr. Loflin recalled Mr. Fleming leading some of the training or explanation sessions that he attended. These training sessions were part of a National Science Foundation Grant. This grant provided a summer workshop opportunity for teachers to explore a variety of classroom technologies. EDU was one of the offerings. Mr. Loflin thought that EDU sounded like it had good potential for use in the classroom. However he only perceived it as an Algebra resource. He did not see any application for the Geometry classroom. The same summer grant program also included training on the Geometer’s Sketchpad® software program. Mr. Loflin acknowledged that he had previous experience with Sketchpad. He felt that incorporating a known technology into his classroom was much more comfortable than learning a new technology such as EDU. Mr. Loflin, although introduced to EDU, never chose to use it in his classroom.

Mr. Williams

Of the participants Mr. Williams had the most teaching experience, 26 years. All of his years of experience had been in service to the MPS school district at the high school level. He held a B.S. in Math and also had a Masters degree in Physical Education. Because of his longevity in the district, Mr. Williams acknowledged that he had taught almost every math course the district had offered for high school students. Concerning his comfort with technology, Mr. Williams described himself as a self-taught individual, “I recognize that I am pretty gifted because I can sit down and take a piece of technology and pretty easily work it through without reading, struggling. There's a natural flow once you get into it. So, it's kind of a natural giftedness thing."

Mr. Williams was one of the first teachers in the district to be introduced to EDU. Because of Mr. Williams's computer skills, he and Mr. Fleming had formed a close working relationship. He was recruited by Mr. Fleming to develop question banks that teachers would ultimately access as they learned to use EDU. Mr. Williams wrote both the Algebra and eighth grade question banks. Both he and Mr. Fleming realized early on that multiple-choice was not the best way to present questions because some students would use a *continual guessing* method to answer the question. They found that open response or multiple-correct multiple-choice problems were better for secondary school students. Mr. Williams spent numerous hours creating labor intensive graphics needed for the geometry portion of the eighth grade question bank. Despite his early and integral role in developing EDU for the district, it was three years before Mr. Williams actually used EDU in a class setting. He was teaching a class for students who were taking Algebra because they had not yet passed this required course. He felt that he needed the computer lab experience to flesh out his two-period long block session of repeater Algebra.

Mr. Hoffman

Mr. Hoffman taught at one of the district's middle schools. He had taught for nine years. Mr. Hoffman had varied experience teaching Math to sixth, seventh, and eighth grade students. He had taught gifted courses, on-grade-level courses, and math intervention classes.

When asked about his comfort level with technology, Mr. Hoffman admitted, “I would say that my experience with technology is limited, not great.” In addition to using technology for his grade book and word processing productivity, Mr. Hoffman’s primary use of technology in his teaching was for accessing EDU and exploring some other favorite math web sites with his students.

Mr. Hoffman learned about EDU via the staff development sessions offered at the time Mr. Fleming was spreading the word about EDU as broadly as he could within the district. Mr. Hoffman, admittedly not as experienced with technology as he would like, took advantage of the expertise of other teachers in his building as he learned to use EDU with his students. Another seventh grade math teacher and Mr. Hoffman cooperated to create a common EDU site. He used this site to present extensive practice assignments and re-mastery assignments for his students to use.

Mr. Hoffman repeatedly commented on how much more efficient re-mastery was when using EDU. He greatly appreciated that the learning curve necessary to get started when working with EDU was easy. He felt it was easy both for himself as a teacher and for the students as they self-selected what they wanted to re-master.

Mrs. Kendal

Mrs. Kendal had been teaching for about ten years. She had a Bachelors and a Masters degree. Mrs. Kendal had opportunity to teach students as young as sixth grade and on up through twelfth grade. At the time of this study she had been with the MPS district for the past three years and had been teaching math to ninth grade students. Mrs. Kendal seemed to be quite comfortable with practical daily use of technology. She used technology for communication and preparing documents. She liked to bring some technology into her classroom by having students explore websites that she had previewed and explored prior to introducing them to her students. Mrs. Kendal described all of the ways she uses technology as, “basic technology.”

Mrs. Kendal’s introduction to EDU began at the same time as Mr. Fleming’s efforts to bring EDU into wider usage within the district. She did not attend any of the formal staff development sessions. However she learned of EDU through several other teachers in her building who were using EDU. Those teachers had been involved in the summer program sponsored through the National Science Foundation Grant.

Mrs. Kendal’s training in EDU had been extremely informal.

> A couple of the math teachers upstairs kind of told us what they had done. And they told us how to set it up. And we did a basic set up with the students’ names and ID’s. And then we went into the computer lab a couple of times. We used it basically for a review, like before a test, instead of doing a review packet.

Mrs. Kendal continued to use EDU several times for the duration of that semester. Visiting with Mrs. Kendal revealed that she recognized valuable strengths of EDU, but did not use it much the following semester. She cited lack of communication and the availability of other resources as reasons for not continuing to access EDU after her first introduction to it.

Mrs. Anderson

Mrs. Anderson had 11 years teaching experience. Seven of those years had been with the district at the middle school level. She had earned both a Bachelors in Math and a Masters in Secondary Education. At the time of this study, Mrs. Anderson was teaching eighth grade math. She also taught math intervention courses for eighth graders and for sixth graders. When asked about her comfort level with technology, Mrs. Anderson responded, “I like to use technology as much as I can.” She then quickly qualified that statement by indicating there were not a lot of moments to actually do that. She was more apt to use technology in classes with a smaller enrollment, such as her math intervention classes.

Mrs. Anderson became aware of EDU during the time that Mr. Fleming was actively conducting district staff development sessions. She attended one of the district wide offerings and also attended two smaller sessions that Mr. Fleming conducted for the Math department at her middle school. Mrs. Anderson's introduction to EDU corresponded with the district's requirement that all students be allowed to re-learn and re-test any math objective not mastered on a chapter test. Mrs. Anderson perceived EDU as a potential tool to assist in remediation for students needing to re-master a math objective.

Mrs. Anderson had used EDU with varying levels of intensity over the past three years. Aside from the problems of securing a computer lab and overcoming student frustration as they learned how to manipulate EDU in the first few lab sessions, Mrs. Anderson remained enthusiastic about EDU's effectiveness in helping her evaluate where students were struggling and in allowing students to self direct themselves as they selected areas needing practice and ultimately re-mastery. Mrs. Anderson commented, "I find those kids that access it or use EDU to do their practice seem like they do better on their re-mastery because EDU [*sic*] makes them redo it until they get it right."

Ms. Selig

Ms. Selig had taught at the high school level within the district for five years. However, in the six to eight years prior to joining the district she had mentored highly gifted students and home schooled her own children. Like Mrs. Anderson, Ms. Selig had earned Bachelors in Math and a Masters in Secondary Education. Ms. Selig modestly described her comfort with technology as,

> basically proficient. I'm not a technophobe, but I wasn't huge into doing all sorts of things of the computer. I mean I use the computer as a tool. That's my function with the computer. You know I'm a user not a programmer.

In Ms. Selig's first year teaching in this district, she was approached by Mr. Fleming about using EDU in one of her classes called Foundations in Math. This course was for last year high school students who still needed to meet the district's graduation requirements for graduation. She agreed. Being fairly comfortable with computers, she spent several hours in the lab learning how to use the EDU program. EDU was used by her students during the following semester. By the end of the semester of EDU usage, the pass rate on the Math Graduation Demonstration Exam (MGDE) more than doubled, going from 39% of the students passing the exam who were in the class the previous semester to 89% passing the exam the semester that EDU was used.

Ultimately, some questions arose concerning the use of EDU with students who needed to pass the MGDE. Ms. Selig commented that EDU was using a multiple-choice format, which was very difficult to make look different than any other test in the same format. She also described how the EDU question writers utilized MGDE practice problems as models for the EDU question banks. To some in the district, EDU apparently seemed to bear too close of a resemblance to the MGDE. Ms. Selig decided to discontinue EDU use in the Foundations class so as not to cast any question on the achievements of her students.

Emerging Themes

Each of the six teacher participants completed a series of interviews. The interviews were conducted using interview protocols and were audio recorded. The recordings were transcribed verbatim. Each participant had the opportunity to review the transcript and verify its accuracy.

According to Spradley (1979), all words, events, or actions of a participant are symbols of the culture under study. As a means to analyze collected data, the qualitative researcher may choose to employ domain analysis. Domain analysis collects symbols into larger groups based on a similarity or relationship. Using these relationships aided in analyzing verbal data.

Each transcript was carefully read. Codes, or symbols, were noted beside each line or passage of the interview that described that line or passage. Spradley (1979) identifies nine universal semantic relationships. A separate reading of the transcripts was conducted for each of the nine semantic relationships. At the forefront of the coding and relationship discovery process was the research question: *How do teachers describe the process of incorporating a new technology software program into their teaching?* At the completion of coding and identifying unifying themes, four salient themes emerged.

- The frameworks of diffusion theory can be used to describe the sequence of events when a school district implements a new technology as a *grassroots* movement, or from the ground up.
- Implementation of a new technology occurs as a result of leadership, software attributes, student benefits, and interventions by district leaders.

- Attributes of the technology and student benefits are reasons for teachers to invest time in implementing a new technology.
- Teachers innovate within the structure of the technological innovation.

Diffusion Theory and EDU Implementation in MPS

This paper began with the story of a boy trying to start a fire using flint and steel. The story of EDU being implemented in the MPS school district can be likened to this story. Three primary stages in implementing the instructional application could be described as the spark (gathering knowledge), fanning the spark (implementation), fanning the flame (confirmation or routinizing),

The spark – gathering knowledge. Individual teachers within the district gradually became aware of EDU, first through word of mouth and later through more formal advertising via district offerings of staff development courses. Often Mr. Fleming was the point man for spreading the word about EDU. Other times teachers would share their interest in EDU with colleagues within their buildings. Regardless of how they learned about EDU, teachers described their gathering of knowledge as informal. The six teacher participants in this study illustrate how teachers learned about the new technology, EDU.

Mr. Williams and Ms. Selig both received a direct invitation from Mr. Fleming to become involved with EDU, "I got a call from Mr. Fleming," Mr. Williams recalled. "He said, 'Would you come down and meet with John Orr. He's going to show us what we can do with this. Come sit in on the meeting.' So that's how I found out." Similarly, Mr. Fleming approached Ms. Selig and said, "Hey, we've got EDU. Let's try this. It would be great for Foundations."

Mrs. Kendal and Mr. Loflin both heard about EDU from their colleagues at their high school. They had brief meetings where they learned some of the basics concerning how to get started using the program. Mr. Fleming was present at one meeting, but mostly they describe their introduction to EDU as being facilitated by other math and science teachers. The other two teacher participants Mrs. Anderson and Mr. Hoffman learned about EDU by attending a staff development session during a teacher workday prior to the start of their school year. As a result of attending the staff development session, two more sessions were planned at their school building.

Rogers (2003) theorizes that individuals pass through five stages in the process of implementing an innovation: knowledge, persuasion, decision, implementation, and confirmation. For MPS teachers, knowledge came by direct invitation, word of mouth, or staff development sessions. Persuasion and decisions to give EDU a try were enveloped in the knowledge gathering stage. In essence the three could be viewed as one stage: knowledge-persuasion-decision. Within an organization, Rogers (2003) calls this the *initiation stage*.

When individuals are part of a system, such as a school system, Rogers (2003) identifies three distinct types of innovation-decision making. He calls these three types optional decision-making, collective decision-making, and authority decision-making. *Optional innovation-decision* occurs when individuals are able to make a decision to adopt an innovation independent of others within the system. *Collective innovation-decision* describes the process of group consensus where the individuals of a system are called upon to choose whether to adopt an innovation or not adopt the innovation.

Authority innovation-decisions occur when the individuals have no choice but to comply because the people in authority make the decision to adopt or reject an innovation.

As a result of the curiosity and desire of one district teacher-leader, Mr. Fleming, EDU was offered to the school district by its original developer. Fleming was able to probe EDU's potential use in secondary level education. MPS is a system, an organization of educators. EDU was not an innovation promoted from the top of the district or even the mathematics department. The diffusion of EDU within this organization, being grassroots in nature, began as an optional decision made by individual teachers. They could choose to try it out in their classrooms or not based on their level of being persuaded that it would be of help in their teaching.

Fanning the spark – implementation. As teachers gave EDU a trial run in their classes, encouragement or lack of encouragement served to fan the spark of enthusiasm to use EDU or to dampen the spark of continued usage. The teacher participants identified a variety of interventions or occurrences that tended to fan their interest in continuing usage of the software program. Mr. Fleming, the primary champion, was a strong force for Mr. Williams, Ms. Selig, Mrs. Anderson, and Mr. Hoffman to utilize the innovation beyond a cursory trial period. Mrs. Anderson and Mr. Hoffman also related a strong sense of collaboration within their building. Mrs. Anderson and Mr. Hoffman also relate that another teacher in their building became viewed as a go-to person if they needed help. Teachers who implemented EDU for at least a semester reported being satisfied with features of the software that helped reduce cognitive load and promoted mastery learning. Teachers admitted that initially they capitalized on student interest in using computers and the diversion that visiting the computer lab gave to their classes. “Kids like to work on computers,” was a common statement of the teacher participants.

Negative factors that may cause some teachers to be discouraged from going beyond a cursory trial period were lack of communication, lack of modeling, difficulty in securing computer labs, lack of knowing how to edit problems to meet the skill needs of students, and the competition of other more familiar teaching resources. Lack of communication and knowledge of problem editing were hurdles for Mrs. Kendal. She related, “I think our biggest thing why we didn’t do it any more was because the question bank that we had of questions was, I think, really hard for our kids. And so we weren’t for sure they were actually learning it or if they were really struggling with it.” Both Mrs. Kendal and Mr. Loflin identified that they reverted to previously familiar strategies rather than work out a new technology. Mr. Loflin had used the Geometer's Sketchpad® in college and had attended training sessions on its use. For him Geometer's Sketchpad® was a much easier technology that he could implement in his Geometry classes than learning to implement EDU. Mr. Loflin recalled, “So EDU [*sic*] never clicked with to me as something that would be helpful. Whereas the Sketchpad, it clicked.” Mrs. Kendal acknowledged her basic computer skills became a barrier to further use of EDU. She ultimately chose safer more familiar technology options,

> If I was more technology capable [*sic*] I could do it myself and just pull EDU [*sic*] up and say okay we’re going to go do this in the computer lab next week, because I could figure it all out. It’s just kind of like; well we’ll just do this because it’s the easier safer way.

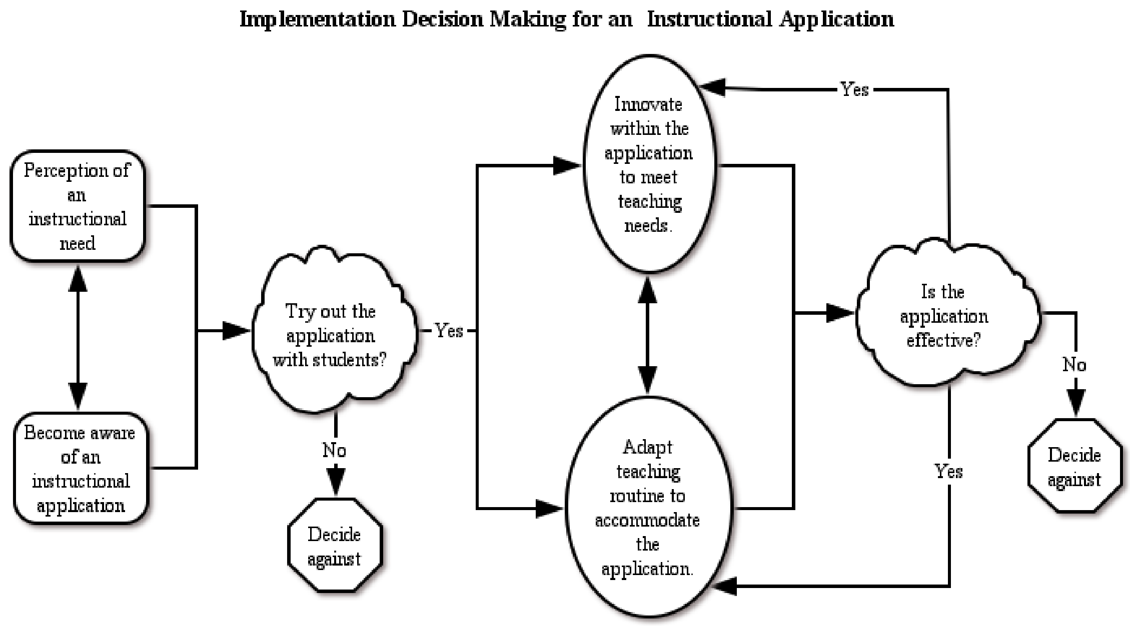


Figure 6. Decision-making diagram.

Fanning the flame –confirmation or routinizing. Just as the shower of sparks from striking flint against steel needs an appropriate amount of oxygen to create a small blaze, so too, teachers need encouragement to continue using a teaching resource. In the case of EDU, teachers reported a variety of influences that caused them to continue using the technology with their students.

Communication and collaboration with other teachers in their building was a strong influence upon teachers' decisions to continued use of the software. Of the participating teachers, two either did not choose to give EDU a trial run or decided not to continue after a short trial use of EDU. Mr. Loflin never used EDU with his students due to the lack of prepared geometry problems in the EDU database. Mrs. Kendal's interest in using EDU initiated with her need to find variety for a block class that lasted two periods long. She relates, “So, a double period class you want anything and everything for these kids to be able to do that’s different. So initially it was let’s get to the computer lab and do something fun and different that the kids would like.” However as she used EDU in the lab for chapter reviews, she noticed that problems she had selected were too difficult for the students to do. Mrs. Kendal did not have the knowledge to be able to edit the problems. When her second semester started and she had a new group of students to enroll in EDU, it was just too much for her and she resorted to safer, easier known strategies in the computer lab. Mrs. Kendal commented repeatedly that had there been more communication in her building that she probably would still be using EDU.

Teachers’ perception as to positive benefit for their students appeared to be a common reason why they continued on with EDU. All of the participating teachers voiced similar thoughts that introducing technology of some type into their teaching tended to be positive. They viewed it as a nice diversion from the regular classroom routine and noted that students seemed to work hard if promised the reward of going to the computer lab.

The participating teachers who voiced strong perceptions of EDU as an efficient teacher tool and as an efficient way for students to learn continued to use EDU beyond a cursory testing period. Mrs. Anderson, Mr. Hoffman, Ms. Selig and Mr. Williams each decided to continue using EDU beyond a trial period. Each were still using EDU or had used it at least a year after their first trial period. All of these four teachers made numerous references to mastery learning and immediate feedback linked with worked examples, corrective feedback, as being a valuable attribute of the software.

The teachers who were still using EDU after a trial period commented on the importance of being able to set EDU to a mastery mode. “It makes them redo it until they get it right,” commented Mrs. Anderson. Mr. Hoffman agreed, “they can’t move on until they’ve mastered that particular kind of problem.” Mr. Williams said, “I used it largely with mastery type. You do it. You keep working this problem until you get it right. You miss it. It’s coming back again. You might as well as sit down and figure it out.” Having a resource that gave students a way to master a skill during practice enabled those students to retake a test and successfully master it.

The teachers who continued EDU usage also observed that students were able to become independent learners because of the corrective feedback feature. After receiving corrective feedback, teachers recalled students saying, “I get it now.” The inclusion of a worked example for students to compare to the work they have done on paper was one way to reduce cognitive load. The teachers reported observing students who took time to review the example and then attempt a new problem. They felt that those students generally seemed to learn from both their mistakes and an example of a correct solution. The teachers observed that students benefited by having a worked example imbedded in their feedback concerning problem accuracy.

The Literature Revisited

Cognitive Load Theory

Much can be learned from the literature concerning cognitive load theory and corrective feedback. The research literature lends support to what the participating teachers observed. Cognitive load theory (CLT) recognizes three general types of cognitive load: intrinsic, germane, and extraneous load.

Intrinsic load is a combination of the complexity of the task paired with the expertise of the learner (Van Merriënboer & Ayers, 2005). Intrinsic load increases as the assigned task becomes more unique or more detailed in its solution. The difficulty of a task, or intrinsic load, can be described as the task's nature. Intrinsic load is difficult to modify.

Germane load are all the parts of a learning task that are beneficial. "Germane load is associated with processes that are directly relevant to learning, such as schema construction and automation" (Van Merriënboer & Ayers, 2005, p. 7). Teachers are able control germane load by selecting the best strategies for a student to learn a specific concept.

Extraneous load are the irrelevant parts of learning that are added to the task of learning a concept, strategy, or skill. It is difficult to reduce intrinsic load because it is the very nature of the learning task. Extraneous load is able to be controlled because it is irrelevant or not necessary for learning the task. A teacher has full control over all extraneous load aspects when teaching students. Controlling extraneous information for students allows more cognitive processing to be devoted to germane load. Doing so creates a more efficient learning environment.

CLT acknowledges that an individual's memory consists of both working memory and long-term memory. While working memory has an infinite storage capability, working memory can only process seven, plus or minus two, chunks of information at one time. It is through working memory that students are able to learn and build schema that are stored into the learner's long-term memory. "Schemas are memory structures that permit us to treat a large number of information elements as though they are a single element" (Clark et al., 2006, p. 28). When information rich schema chunks become one or more of the five to nine elements in working memory, the learner becomes more efficient and becomes more expert in his or her problem solving.

Teachers strive for efficiency of learning in their classrooms. If a teacher can efficiently deliver instruction and have it retained by students, more time is available for deepening the knowledge of the subject content and for enrichment activities. Educational technology has become a mainstay in the modern classroom. New technologies can utilize human cognitive processes but cannot change those processes.

> Educational technology keeps advancing and can be expected to continue advancing indefinitely. Our knowledge of human cognitive architecture equally keeps advancing and also can be expected to continue doing so indefinitely. Nevertheless, there is a constant. Human cognitive architecture itself does not change except over long, evolutionary periods." (Sweller, 2008 p. 32)

Five principles of human cognition architecture are identified: the information store principle, the borrowing and reorganizing principle, the randomness as genesis principle, the narrow limits of change principle, and the environmental organizing and linking principle (Sweller, 2008). The information store principle pertains to an individual's long-term memory that is accumulated over years of learning. Learning adds to the long-term memory storehouse. The borrowing and reorganizing principle describes how a learner gleans information from other individuals' memory and incorporates that knowledge into their own memory. Direct instruction is an example of borrowing and reorganizing. The randomness as genesis principle identifies two methods an individual goes about when problem solving. The learner first utilizes the borrowing and reorganizing principle and then tests to see if the problem solving method is effective. The individual then retains effective strategies and dismisses ineffective strategies.

The narrow limits of change principle cautions that attempting to store large amount of information at one time is not likely to occur. Instead individuals store information in small chunks at a time. Finally the environmental organizing and linking principle describes how an individual can draw upon knowledge stored in long-term memory and utilize that knowledge to incorporate and organize new information into long-term memory. “The characteristics of working memory change dramatically depending on whether it is dealing with novel unorganized information from the environment or familiar, organized information from long-term memory” (Sweller, 2008, p. 34).

One goal of mathematics instruction is to nurture problem-solving skills in students. Discovery learning is an educational movement that promotes the development of problem solving skills by allowing the student to explore and discover a strategy for solving a problem. This method requires a large amount of cognitive processing which demonstrates the randomness of genesis principle.

Students with expertise in solving problems generally will begin with an equation that they know is appropriate for the problem. Using that equation they will work forward toward the final goal of the problem. However a novice learner is not able to access the required equation from stored memory because it has not yet been learned and is not available in his or her long-term memory. Instead of drawing upon stored problem solving strategies, the novice generally uses a means-ends analysis of the problem and works backward from the goal. He or she works to find small portions of the solution until all the variable pieces are filled in.

Sweller (1988) cites how means-ends analysis interferes with learning. Means-ends analysis requires learners to split their attention. They must recognize the difference between where they want to be at the end of the problem and the place they are currently at in solving the problem. A large amount of cognitive processing is required to consider the new pieces of the current problem and to search for potential ways to solve the problem. This presents a disadvantage for learning.

> Under most circumstances, means-ends analysis will result in fewer dead ends being reached than any other general strategy that does not rely on prior domain-specific knowledge for its operation. One price paid for this efficiency may be a heavy use of limited cognitive-processing capacity. In order to use the strategy a problem solver must simultaneously consider the current problem state, the goal state, the relation between the current problem state and the goal state, the relations between problem-solving operators and lastly, if subgoals have been used, a goal stack must be maintained. (Sweller, 1988, p. 261)

A learner who is so intensely focused on reaching the end goal will not have enough cognitive space to devote to creating schema for solving the problem, which hampers organizing it into long-term memory.

> Most mathematics and mathematics-based curricula place a heavy emphasis on conventional problem solving as a learning device. Once basic principles have been explained and a limited number of worked examples demonstrated, students are normally required to solve substantial numbers of problems. Much time tends to be devoted to problem solving and as a consequence, considerable learning probably occurs during this period. The emphasis on problem solving is nevertheless, based more on tradition than on research findings. There seems to be no clear evidence that conventional problem solving is an efficient learning device and considerable evidence that it is not. If, as suggested here, conventional problems impose a heavy cognitive load that does not assist in learning, they may be better replaced by nonspecific goal problems or worked examples. (Sweller, 1988, pp. 283-284)

Worked Examples

An efficient teacher understands the limitations of an individual’s working memory and how to reduce strain on those limitations. Learning is most efficient when students focus the majority of their cognitive resources on what is essential for learning (Mayer & Moreno, 2003). Educators must consider the principles of human cognition architecture, when planning instruction and when using new technology as a part of their instruction. Using worked examples is one method of working with, not against, the principles of human cognition. The study of examples "is a type of germane cognitive load that leads to schema development in long-term memory" (Clark, Nguyen, & Sweller, 2006, p. 34).

> Many instructional effects have been demonstrated. The worked example effect is one of the most heavily studied and best known. If you present learners with worked examples to study, they will learn more and perform better on a subsequent problem solving tests than if you present them with equivalent problems to solve. (Sweller, 2008, p. 34)

A teacher is working the borrowing and reorganizing principle when he or she models how to work a problem for the student. Without the model, the student will have to actively search for the required problem solving steps, which puts them in the randomness as genesis principle.

> Nothing is gained by having learners engage in a process of random-generate-and-test; and, due to the heavy extraneous cognitive load associated with random–generate-and-test, limited working memory resources are wasted in a largely useless activity. Given a choice, always show learners how to do something rather than have them attempt to re-invent the wheel. (Sweller, 2008, p. 34)

Use of worked examples can alleviate extraneous load for learners. By providing a step-by-step sequence for solving a problem the student is able to study the model and then apply the same sequence to a new practice problem. When the worked example integrates descriptions of the steps with the modeled problem further reduces cognitive load. The learner does not have to split his or her attention between the descriptive text and the model, "eliminating the need to use working memory resources to mentally integrate the two sources of information" (Kalyuga, Chandler, Tuovinen, & Sweller, 2001, p. 580).

> Studying worked examples reduces or eliminates the cognitive load associated with problem solving search and replaces it with activities that involve considering relevant problem states and their associated moves. Learning to recognize problem states and their associated moves is integral to schema acquisition. (Pawley, Ayres, Cooper, & Sweller, 2005, p. 77)

Students report less mental effort is required in order to complete practice work which pairs worked examples with practice problems than to complete conventional practice problems (Paas, Van Merriënboer, 1994). In addition to less cognitive strain the students were able to complete the work in half the time and with less errors. The transfer of learning as noted by performance on a post-test also resulted in more accurate performance by the students.

> Better and less effort demanding transfer performance in the worked conditions suggests that a considerable part of the mental effort in the conventional conditions was invested in processes that were not relevant for learning. . . . The positive results of the numerous studies on the effects of instruction with worked examples on transfer are overwhelming. (Paas & Van Merriënboer, 1994, p. 131)

The use of worked examples should also take into consideration the skill level of the targeted learner. When the learner has already developed schema and is able to access that information from memory, then worked examples are not as effective. In fact having to study worked examples for problems that an individual already knows how to do may impose redundancy and serve to clutter the working memory with extraneous information. However for the novice learner, research supports worked examples as an efficient and effective form for learning.

Domain Analysis Themes: Cause-Effect

Two semantic relationships emerged that helped to describe the implementation of the web-based software program: cause-effect relationship and rationale relationship. An examination of the cause and effect semantic relationship revealed four relationships that resulted in the implementation of the software. Implementation occurs as a result of appropriate leadership, the attributes of the software, observed student results, and the interventions of the district.

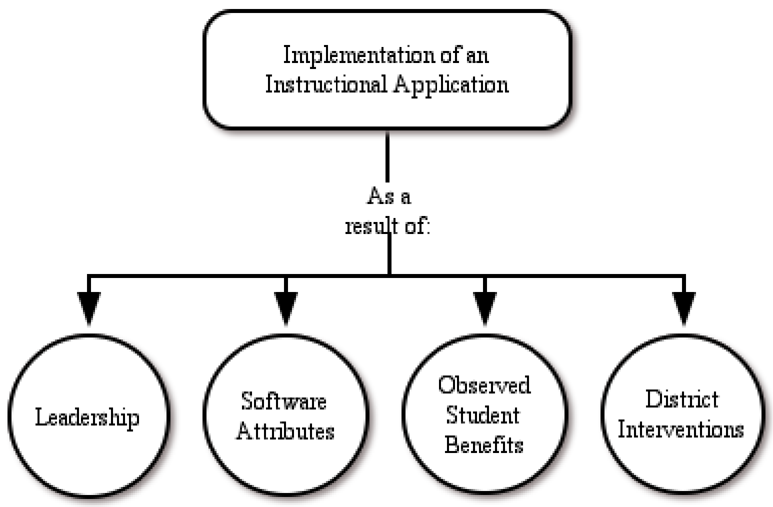


Figure 7. Domain analysis: cause-effect relationships.

An examination of the rationale semantic relationship revealed three areas of interest. Three relationships emerged which help to describe why teachers are interested in trying out a new technology, why their students benefit from using technology, and why a teacher will innovate or try something new with technology.

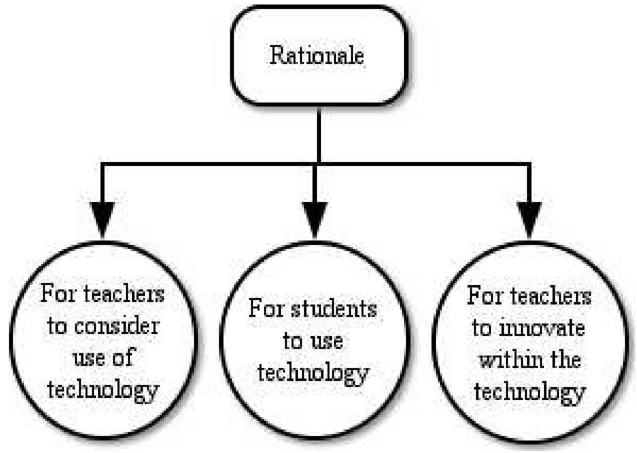
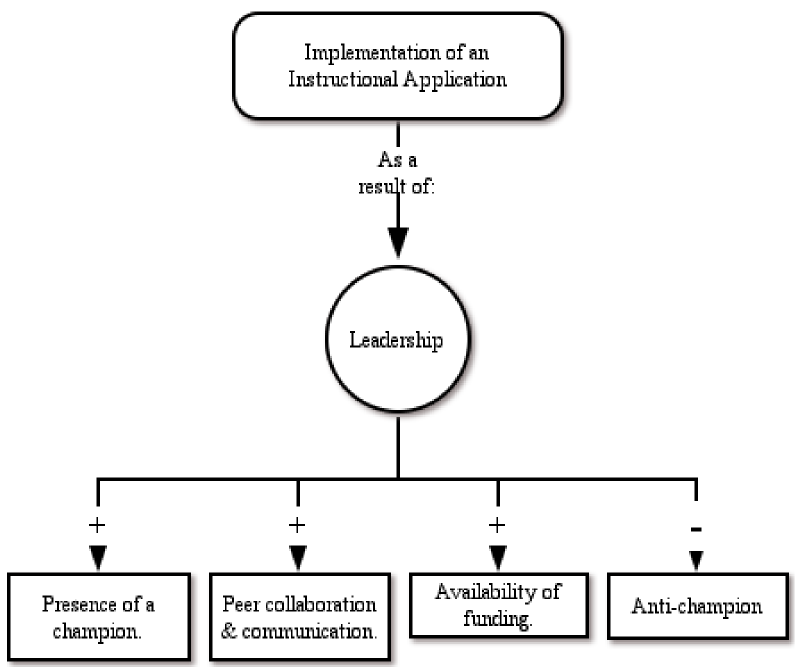


Figure 8. Domain analysis: rationale relationships.

Cause-effect relationship: implementation occurs as a result of leadership. Leadership, or the lack thereof, greatly affected the decision making process of individual teachers as they chose whether or not they would implement the software, EDU, into teaching routines.



(+ or – denote positive or negative affect)

Figure 9. Implementation as a result of leadership.

Implementation of an innovation occurred as a result of the intervention of leaders, specifically a champion. “A champion is a charismatic individual who throws his or her weight behind an innovation” (Rogers, 2003, p. 414). The actions of an anti-champion could, conversely, deter an innovation from being adopted.

In this particular case that examines a software program being implemented in a public school district, three leadership or champion figures were evident. Mr. Fleming functioned as the primary champion figure for EDU within the district. He actively sought out information after he learned that a recently developed software program, with great potential, was being utilized on the university campus. He found a way to get himself accepted into training seminars for university faculty. Mr. Fleming took what he learned to his district and began to try it in the teaching laboratory, which were class settings with students. Observing how students interacted with and apparently benefited from the software served to increase his enthusiasm for exploring its potential on a broad scale within the district.

Over the course of the succeeding six years, Mr. Fleming actively recruited individuals who could help make the implementation within the district possible. Each year saw small steps toward the vision that this software might be useful for the district’s math teachers to adopt into their teaching and utilize in their classrooms. Ultimately he made a large-scale effort to acquaint as many interested math teachers with the software as possible. He worked with the university on a National Science Foundation (NSF) grant, which included EDU as one of the technologies that participants in the program would experience. Through this same grant, Mr. Fleming was able to hire one of the district’s teachers as a writer of problems that would be uploaded as question banks for other district teachers to access. Mr. Fleming realized that EDU held great potential as an application from which low-achieving students could benefit by gaining mastery over math skills. This eventually led to a relatively large explosion of interest in EDU by math teachers within the district.

The teachers interviewed identified Mr. Fleming as the key person who got them started working with EDU. He either had personally invited the individual to be a part of the development of EDU within the district and to give EDU a trial run or he taught staff development sessions that were offered by the district. Mr. Fleming aggressively accepted invitations by small groups of teachers to come to their building and help them set up EDU for their students. He welcomed e-mail or phone calls concerning questions dealing with the software.

A second champion figure was the developer of the software who was from the university. He was an early champion for the implementation of EDU in the public school district. As a result of this champion, MPS gained access to the software at no expense to the district. He even made it possible for MPS to use the software via the university servers. In addition to basically giving the district a free program, he willingly worked with Mr. Fleming in training the initial teachers who were learning how to write EDU questions for the EDU question banks.

A third champion figure emerged at the building level. During the early implementation phase, this individual could also be thought of as a building champion. Mrs. Anderson and Mr. Hoffman describe such an individual at their building.

Mrs. Anderson noted that one teacher in her building “grasped on to it and learned it a lot faster than a lot of us. We always had that resource that we could come back to. That helped." This individual became the go-to person when there was a question or difficulty with the software. The building champion, or perceived software leader, served to help the teachers in that building settle into a type of routine in their usage of EDU. After a semblance of routine took effect that champion figure declined in importance. Mrs. Anderson noted that once EDU was up and going for her she really didn't need to access outside help very often. As the building champion faded from prominence, the teachers seemed to have developed a comfort and familiarity with the software similar to the building champion**.** Mr. Hoffman noted that using EDU became a common tie between him and two other teachers who also used the program.

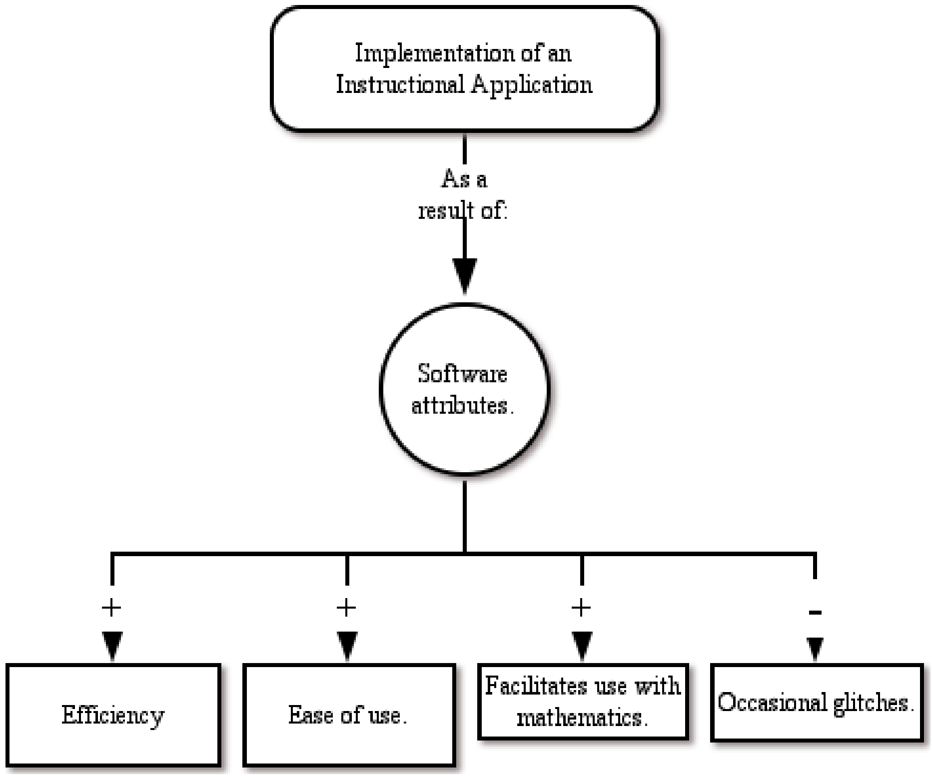
Champion figures were very important leaders as teachers implemented EDU. A second form of important leadership was the modeling and collaboration by other teachers, which was exhibited within buildings. Mrs. Kendal learned about EDU from other teachers within her building who were talking about it. She recalled, "one time a math teacher just mentioned you could get all these great review questions that are already made up for you." Mr. Loflin commented that he acquired awareness of the software by observing another teacher who was using EDU at the time. He remembered, "I would have learned it through another teacher who teaches here and is a lot more familiar with it. I don't know if he either showed me some things or did a lesson, but I remember hearing about it that way." Mr. Loflin described how Mr. Fleming later conducted an in-service in his building that he decided to attend. Mrs. Anderson talked about how, after she had been using the software for a while, she later became a type of champion or leader or model for another teacher on her grade level team who was beginning some use of the software program. This colleague now comes to her for questions that he has about accessing and using EDU. The leadership torch in essence was being passed on as teachers became accustomed to working with the software in turn model and collaborating with other teachers.

A third source leadership came in the way of finding funding for individuals who learned about EDU or worked on developing EDU outside of their contractual agreement with the school district. When the university needed help with the NSF grant, they contacted Mr. Fleming and requested his assistance in finding a person who could produce a presentable product of EDU. This event caused Mr. Williams to be paid for his time writing questions for the Math 8 EDU question bank. Mr. Williams concedes that funding is critical to shift his focus from courses that he does teach toward curriculum areas that he does not teach, " I've said all along I'd love to do it with Pre-Cal, but if somebody's going to pay me to write curriculum for them versus me writing something for my own class, hey, you know which one I'm going to choose." Interestingly, not until three years after writing the Algebra curriculum for EDU did Mr. Williams have the opportunity to use his own efforts, "So I never really, did something with EDU [*sic*] that I had a strong personal interest in until now. I started teaching the repeater Algebra last term. It was really the first time I sat down and really used what I've actually done." Mr. Loflin echoes Mr. Williams's sentiments concerning the need of funding for teachers who train outside of the contractual day. Mr. Loflin honestly admitted that part of the reason that he attended the weeklong summer workshop, sponsored via use of the NSF grant, is that those participants received a stipend for their summer time.

Anti-champion-like influences were more indirect rather than overt. Mrs. Kendal associates her lapse in using EDU partially due to the lack of communication and leadership within her building. After the initial flurry of activity when she first learned of EDU, there was very little discussion, if any, about how people were using EDU or encouragement to use the software to some extent with classes. She feels that if it had been brought up at department meetings or in more casual conversations between colleagues, perhaps she would have continued using EDU more.

While Mr. Fleming was not officially the EDU liaison, he took on that role in the district. Mr. Fleming retired at the end of the year where he made a strong effort to spread EDU through out the district's secondary math teachers, focusing on remedial courses such as Math Intervention. His retirement served to halt the flow of communication within the district. Teachers did not know who was in charge of EDU and unless there was a strong commitment to using EDU within the building often teachers believed it went away when Mr. Fleming retired.

Cause-effect relationship: implementation occurs as a result of software attributes. Implementation of an innovation occurred as a result of the software's attributes. The teachers revealed through their interviews that the innovation being implemented commanded a strong influence on their decision to implement the software. Teachers described increased efficiency and ease of use as attributes of the software that increased their interest in implementing the software.



(+ or – denote positive or negative affect)

Figure 10. Implementation as a result of software attributes.

Teachers who had used EDU intensively for one or more semesters noted an increase in their own productivity or efficiency. Mrs. Anderson appreciated how EDU facilitated her formative assessments of student learning,

> I use it more as a formative kind of thing. It's a quick evaluation for me because I can see quickly, especially if you do it on that mastery level where they have to redo it and redo it until they get it right. It helps me evaluate. "Okay. Are they understanding this or are they not understanding this?

The teachers could also access the software's grade book feature to check the digital report of a student's progress on EDU if they so chose. However most teachers used their observations and interaction with students in the computer lab as an evaluative tool.

Teachers valued EDU's ability to help them efficiently manage a group of students who all need to work on different lessons or objectives during one class period. Mrs. Anderson observed,

> I like having the computers in my room and if kids choose to do re-mastery, re-testing, they can do that. It's a quick thing. Or even if kids want to do the practice at home and then do re-mastery after school, I really enjoy that.

Mr. Hoffman agreed,

> It just made life easier. You're just not coming up with five problems to test them on and then having to grade it and then come up with practice problems and if they don't do well on those come up with more problems. This, EDU [*sic*], automatically generates that for you so it's a lot less of a paper trail. Especially where you have kids at so many different spots at once. You know to sit and come up with all the different objectives and be able to have copies of it to pull out all the time wherever they might be. It just would be a management nightmare, I think. I don't know how other people do it. I really don't.

Mr. Fleming's foresight in having pre-built question banks facilitated efficiency as teachers were first learning to use EDU. Mrs. Kendal affirmed, "You could just go through and pick the questions you actually wanted. I mean there was a gazillion questions on there." Mrs. Kendal also cited ready availability of question banks helped alleviate the time crunch many teachers experience. They were a resource ready to be accessed as needed.

A unique feature of EDU, Mr. Williams asserted, was its power to understand mathematical language. "So the first thing that caught me was the fact that here's a system that can say y = 2x + 3 is the same as y = 3 + 2x. And it doesn't matter whether you put two spaces between the plus, one space, or no spaces. It can interpret it." He adds,

> You add in the random number availability and the student can work the same question over again and never ever know it because the numbers are different on

> it. Or two students can be sitting side-by-side and have the same basic [*sic*] problem and they don't even realize they are the same problem.

Efficiency for the teacher seemed to imply more time for the student. "It's maximized my ability to touch base with more students," Mrs. Anderson noted. "When I use it as maybe a quiz review or a chapter review, those kids that get it can practice and it [*sic*] gives me time to work with those kids that are struggling."

Teachers often mentioned the lack of time to do all that they are required to do. Having a new technology that is perceived as user friendly increased their willingness to start using EDU and also affected their decision to continue using EDU after a trial period. Each of the participants in this study noted that not much training was needed to get started using EDU. This was primarily due to the previously prepared question banks. Teachers described EDU as an innovation that was ready to go for most teachers.

Ms. Selig taught a class called Foundations at the time she first was asked to implement EDU into use with students. Foundations was a class for high school students in their last year who had not yet met their mathematics requirements for graduation. She recounts her experience with getting started implementing EDU.

> So Mr. Fleming came to me and said, "Hey we've got EDU. Let's try this. It would be great for Foundations." And "Here, I set this up. Here's how you use it. Just go in there and play with it and take your class."

Ms. Selig recalled thinking, "You want me to do what?" She spent a couple of hours one evening exploring how to select questions and set up the assignments for the students. She admitted,

> My computer skills were fairly good and I didn't have that big of an issue. You know we bookmarked the EDU pages in our browser and had them ready and got all our pass codes put in. But it was very easy. I mean a quick start-up.

Another participant with above average computer skills was Mrs. Anderson. She describes her training on EDU as a couple of hour long training sessions which covered everything from entering student logins and passwords into EDU, setting up student assignments, and a little bit on editing question bank problems. She credits teacher collaboration for most of her training, “So a couple of training sessions but mostly we have trained ourselves or trained each other, I think. Working together.”

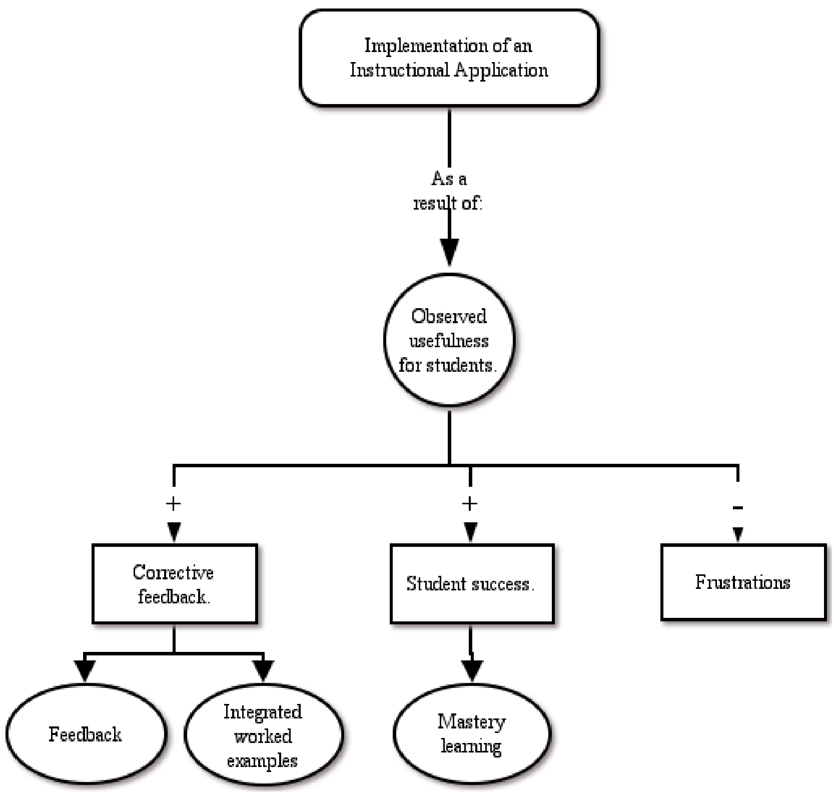
Mrs. Kendal did not describe her computer skills as much beyond basic. However she recalled her EDU training as quite brief but enough to start exploring EDU’s usage with students,

> Basically it was one of the math teachers and I think one was head of the science department. He was our technology guru. The two of them just sat down with the other teacher and me. And just went through how to set the names up in the computer that we had to have in there before the kids could actually log on. The math teacher showed us how to set that up so we could select only those thirty questions [*sic*] and that’s what the kids would be working on. So really in terms of training they just kind of talked us through it before we ran it in our classrooms.

Like Mrs. Kendal, Mr. Hoffman does not consider his computer skills to be above basic usage, but he also stated, “to make a little quiz or anything like that is really simple.”

There were a few difficulties that teachers encountered when using EDU. One difficulty that teachers encountered when using EDU resulted because EDU was hosted on a server at the university. The university and the public school district did not share a common schedule. When the university was on a break, often times the teachers using EDU in the public schools found that there would be a message concerning the server not being able to be accessed. Apparently the university would work on their servers during their breaks unbeknownst to the public school teachers. This interruption to service did not occur often but teachers noted that occasionally they had to scramble for alternative activities if it did occur on their lab day.

Cause-effect relationship: implementation occurs as a result of observed usefulness for students. Implementation of an innovation occurred as a result of observed usefulness for students. In addition to their conversations about teacher efficiency were the teacher's opinions about how useful EDU was for their math students. Corrective feedback consists of a report back to student that indicates if their solution was correct coupled with a worked example explaining how to arrive at the correct solution.



(+ or – denote positive or negative affect)

Figure 11. Implementation as a result of usefulness for students.

Mr. Williams considered EDU's most powerful feature to be the immediate feedback that could be given back to the student. Other participating teachers described an increase in student confidence as a result of receiving corrective feedback. Ms. Selig related,

> But then, all the wonderful benefits of any self-paced learning with immediate feedback were there. I mean the kids' attitudes were, "Wow, I can do this all by myself." And, "I don't have to have you help me with every question because look it tells me if I got it right or wrong." So it was a positive experience for these guys. They liked the immediate feedback. They liked that they could work at their own pace and they were not held back by their peers.

Mrs. Anderson noted student confidence grew, as students were able to use the worked out example as a means to teach themselves instead of calling on the teacher every time they had a question, "most of them, once they see that, they get the idea of, 'Oh, I can figure that out."

Mr. Hoffman observed student success as a combination of a different approach to a lesson as well as feedback and mastery.

> They (the students) [*sic*] liked it. I think it was more successful just because it is something different. Plus it is immediate feedback. They know right then and there if they got it wrong. And if they use it right, they can see why they didn't get it correct.

Mastery mode in EDU requires a student to successfully complete each type of problem assigned in order to complete the assignment. Incorrect solutions result in the student receiving an additional problem of that particular type. Students learned to be accountable for their time and learning. "They kind of work at their own pace. They can't move on until they've mastered that particular kind of problem." Mr. Hoffman related. Mrs. Kendal tells how students quickly learned that it was better to work a problem out on paper and get it correct rather than continually receive a replacement problem to work.

In Ms. Selig's first year teaching in the district, an event occurred in her Foundations class that set the stage for Mr. Fleming to promote EDU to a wider audience in the district. In addition to ensuring that these students have met all the objectives that any high school graduate should know, the students knew that this class would help them be prepared to pass the MGDE. When her first semester students took the exam, Ms. Selig reported that there was a 39% pass rate. Towards the end of that semester Mr. Fleming asked Ms. Selig to try EDU as an extra tool in her classroom. She agreed. She tried to have a weekly EDU review session on Fridays. At the end of second semester, Ms. Selig reported an 89% pass rate on the MGDE.

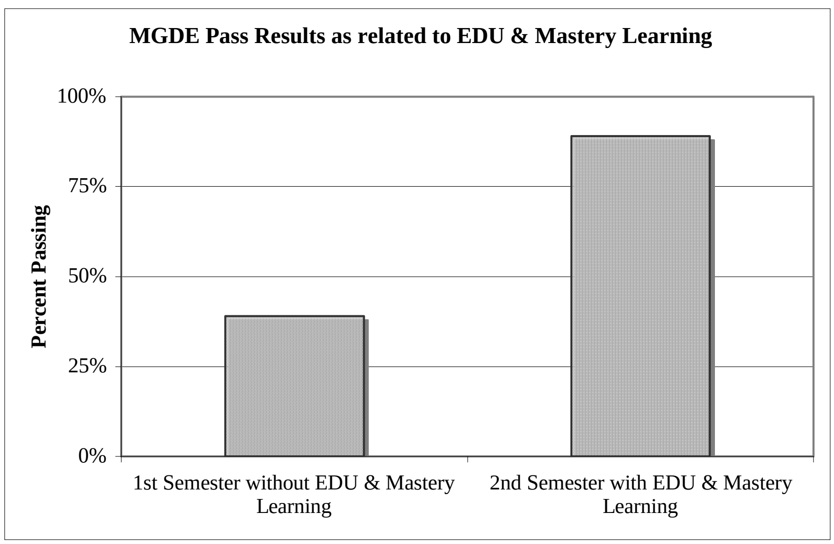


Figure 12. MGDE pass results.

Ms. Selig noted that second semester also differed because she knew more of what was required on the MGDE. Ms. Selig asserted, "with the immediate feedback in EDU [*sic*] and me knowing a little bit more about the test [*sic*] . . . we had a huge, significant jump." This success event with low achieving students served as an incentive for other teachers to experiment with implementing the software.

Mastery was a strong component in the success story of Ms. Selig's Foundations class. Students were required to achieve 70% correct on both their paper homework and in their EDU practice.

> I think that had a significant impact, too. So the whole stress of second semester when we had the EDU was we are going to keep doing this until you can do it proficiently. So EDU was one of the tools that really helped. 'You don't get out of this quiz bank until you've got a 70%. And you're going to get that same question type until you can do it. So it really made their study time more efficient in the lab. Because the ones they knew how to do, they didn't get thirty of those. It was just the ones they didn't.

As a result of the significant increase in the MGDE pass rate of the Foundations students, Mr. Fleming began to accelerate his promotion of EDU within the district. He especially felt that EDU could be a huge advantage for students in remedial type classes such as Math Intervention in the middle schools and repeater Algebra in the high schools.

Frustration was also a part of the EDU learning experience, both for teachers and for students. Teachers noted their frustrations stemmed primarily from student frustrations. When first learning how to use EDU students generally had a multitude of questions. Unless the teacher was fortunate enough to have an assisting teacher in the lab with them, it was difficult to get all student questions answered efficiently.

Mrs. Anderson illustrates such a scenario when she had a group of students in the lab,

> Well, if I choose mastery and if they don't understand it, and they're continuing to not understand it. And if [*sic*] you have 28 kids in a class, you can't get to them immediately. "Tell me how to do this." And their partners next to them aren't able to [*sic*] help, you know. So, that gets to be a frustration, too. That makes it tough, too. When I have found it's most successful is [*sic*] in a small classroom setting. It's great if there's more than one adult. But like my group of 28, when it was just me, that was pretty tough.

Cause-effect relationship: implementation occurs as a result of the interventions of the district. Implementation of an innovation occurred as a result of district level interventions.

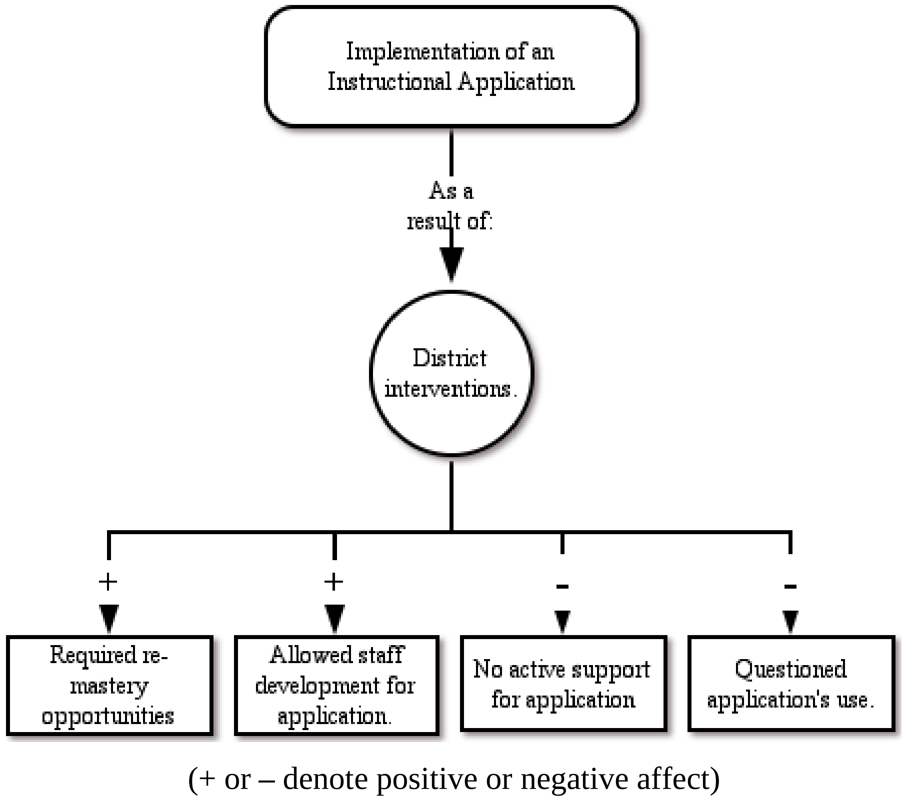


Figure 13. Implementation as a result of district interventions.

The district began to require that teachers offer opportunities for students to re-master math objectives as needed at about the same time as Ms. Selig was teaching her first Foundations class. Teachers had experienced the burden of re-teaching and re-testing and were discovering ways to manage this requirement efficiently. EDU's capability to address mastery was viewed as a timely intervention by some of the district's mathematics teachers. Mrs. Anderson recalled,

> It came about the time we were focusing on re-mastering, re-testing. I thought, wow, what an excellent opportunity for the kids to have another resource for them to practice and to do re-mastery. Because having them do the practice out of the book and coming in and testing was not always working the best that it should.

Had the district not focused on re-mastery as a requirement the need for EDU may not have been as apparent to those who chose to implement it.

The district allowed Mr. Fleming to conduct two official staff development sessions that counted toward a teacher's professional development requirements. Approximately 50 teachers noticed and participated in these opportunities. Two of the participants in this study learned about EDU through these staff development sessions. Two other participants knew of the sessions but received their training on EDU through peer mentoring at their buildings. As a result of the staff development sessions Mr. Fleming set up EDU sites for each of the district's middle schools. Some schools had active advocates of EDU use and others did not.

Both requiring re-mastery and allowing EDU staff development sessions had a positive affect on the implementation of EDU. However not all of the district's interventions were positive. The district never acknowledged that they gave support to EDU being implemented in the district beyond providing time for Mr. Fleming to conduct staff development sessions. The district math curriculum specialist maintains that it is not technology that influences a student's learning, but it is what a teacher does with the technology that affects change in learning. The mathematics department at the district level does not advocate for advanced technology in math classroom except for scientific calculators and statistics software.

When Ms. Selig's Foundations class achieved a very high pass rate on the MGDE, the district did not exhibit enthusiasm for the use of EDU. In contrast it appeared that they were suspicious of its usage. As a result of the “raised eyebrows” as Ms. Selig called it, she chose not to continue using EDU. Her rationale was that she did not want any question to be put on her students’ achievements.

Domain Analysis Themes: Rationale Relationships

An examination of rationale relationships revealed two areas of interest. One relates to teachers and the other to students. Teachers described why they might consider using or trying out a new technology. Teachers identified reasons for why students might benefit from the use a new technology. Teachers considered why they found ways to be innovative with the technology.

Rationale relationship: why teachers might consider using or trying out a new technology. The participants in this study found it an encouragement to use, or at least try to use, a new technology if certain conditions were present. It must have a quick start up. It must meet their needs. There must be observable results and it must be glitch free.

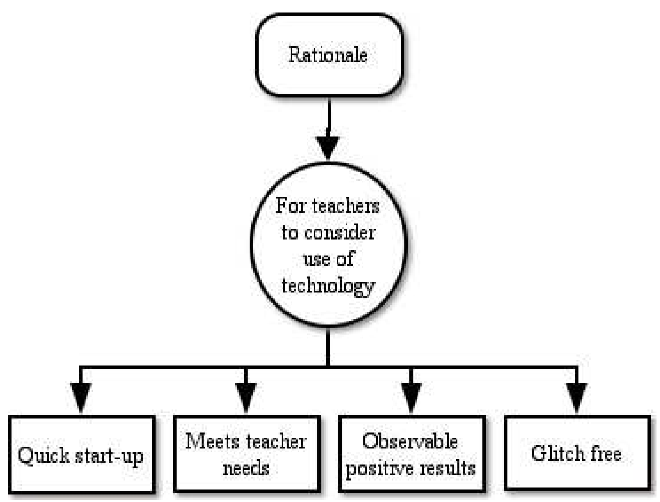


Figure 14, Rationale for teacher use of technology.

Ms. Selig sums it up this way,

> It's got to have a quick start up. You've got to be able to get into it and use and see results quickly. Teachers have to see results and students have to see the results. It it's a program that doesn't work or has glitches in it or what ever, then that's really frustrating. But to catch fire – necessity – pretty much if you're not seeing that it works or you need it to work, it's not going to get done.

Participants in this particular case, concerning the implementation of a new technology, noted reasons that EDU was interesting for them to try using. Quick start-up was a priority. Each of the participants identified the ease of starting EDU up in their classrooms. A large investment of time just to get a technology going in their classroom prevents some teachers from getting started. The start up for the teachers was very quick as a result of Mr. Fleming arranging for prepared question banks to be in place before he recruited teachers from the district on a wide scale. Mr. Fleming also set up individual school sites for teachers to access as they began their exploration of EDU.

The ways that EDU met teachers' needs were varied. Teachers desired that their students be successful. They wanted their students to demonstrate an increase in learning. Most of the participants recalled starting their use of EDU with a review assignment. Rather than use EDU as a way to introduce a new concept or lesson, teachers saw it as a potential way to provide reinforcement activities, reviews, extra practice, and re-mastery opportunities for their students. Teachers also acknowledged that they saw this software as a way to increase student motivation and help reduce boredom with traditional class activities.

Each of the teachers, who participated in this study and did choose to give EDU a try, taught either Math Intervention at a middle school or a repeater Algebra at a high school. They each had hopes that EDU would help them meet the needs of the low-achieving students that made up their classes.

All of the participants, except Mr. Loflin, were able to access questions appropriate to their curriculum from the EDU question banks. Mr. Loflin never really used EDU because of the lack of geometry questions for his Geometry classes. The task of creating questions complete with diagrams was beyond his technology skills.

Mr. Loflin chose to use a software program that he was more familiar with in his classes. Mr. Loflin's experience is an example of how important it was for appropriate questions to be prepared and available for teacher use, thus meeting a teacher's needs.

Teachers needed to observe positive results. As the participants used EDU with their students, they began to see results. Some were positive and some were not. Initially, teachers reported that students were very needy as they learned to navigate the program, log in, and work through an assignment. Mrs. Kendal recalled,

> It was just going around one by one and it was kind of like, just calm down, wait. But when they are on a computer, they want to know what they are supposed to do and they want to get to it because they like to work on the computer. If they have to wait and raise their hand, they just get kind of antsy. So that makes me feel helpless.

Having an extra teacher, co-teacher, or lab assistant would have helped relieve the initial confusion in the lab. But after students had been to the computer lab a couple of times, this was not an issue. Mr. Hoffman notes, "Once the kids have been trained on how to use it, they can go right to it themselves and pretty well be self-reliant."

Teachers really liked the immediate feedback that the program gave students. This aspect of EDU allowed students to work independently and allowed the teachers to spend more time with students who did not understand how to proceed with a problem.

For the most part teachers did not complain about annoying reoccurring software glitches. Teachers did not perceive EDU to be laden with errors that continually made working with the software frustrating to both teacher and students. The most common frustration came from the teachers not knowing how to edit questions and adapt them to an appropriate difficulty level for their students. Some teachers could not get past this hurdle. Other teachers did not let this inadequacy on their part to squelch their usage of EDU. Except for Mr. Williams, each teacher expressed their need and desire to be more knowledgeable in the writing of problems giving them more control over the types of problems they included in their EDU assignments. Mr. Fleming's retirement occurred too early in the implementation of EDU for in depth teaching on problem writing to occur.

Rationale relationship: why students might benefit from the use of a new technology. Teachers recognized several benefits for students using EDU beyond deeper learning about mathematics. When in the computer lab, teachers reported that students would question themselves as they examined feedback related to their solutions.
Ms. Selig noticed students asking, "Okay, that was the wrong answer. What do I need to do differently on the next problem to get the right answer?" Teachers noticed that students would engage in peer tutoring when in the lab. Mrs. Kendal described how one student was having difficulty with a problem and was becoming frustrated. A neighboring student, who had worked it out on paper, leaned over to show the math steps to the frustrated student. Teachers appreciate the learning conversations as students collaborated with each other.

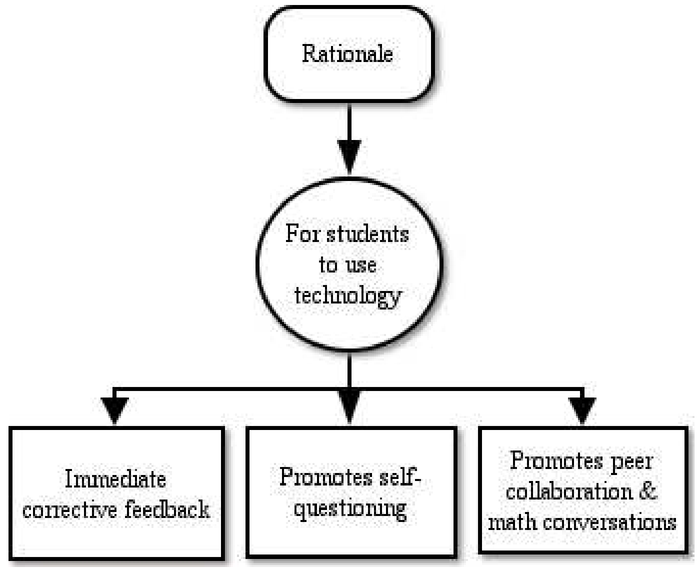


Figure 15. Rationale for student use of technology.

Rationale relationship: why teachers find ways to be innovative within the technology. Accommodating student needs initiated a teacher's desire to be innovative. Mr. Fleming and Mr. Williams recognized early the power of developing the corrective feedback feature. They observed that formerly feedback generally was given as a verification of correct solutions. Mr. Williams related,

> To me the innovative piece was the feedback piece. Most of the content that I saw developed when I started developing was merely for the ease of an instructor to get grades and that distance learning type of thing. To take a common test and be able to assimilate that and to get feedback, to get numbers, to get comments. And most people did not put hardly any comments on. You got the box with the green checkmark or the red X and that was all you got. And so I think our innovative piece was saying we're going to invest a significant amount of time in the feedback portion.

The participating teachers often cited immediate feedback accompanied with a detailed explanation as EDU's most important feature.

Mr. Williams recalled how surprised he was at one teacher's use of EDU. Mr. Williams was a math teacher and all the other teachers he knew that used EDU were either math or science teachers. When Mr. Fleming approached him and asked how they might include recorded words in EDU problems, Mr. Williams notes, “I mean Scott is Science, Frank is Science, I was Math and there were some other math teachers. And then all of a sudden she comes in and says: I’m using it for spelling.” In addition to EDU’s usage for spelling, that same teacher introduced the use of the EDU software to the district’s high school media specialists. The media specialists used it to assess all incoming high school student’s media skills.

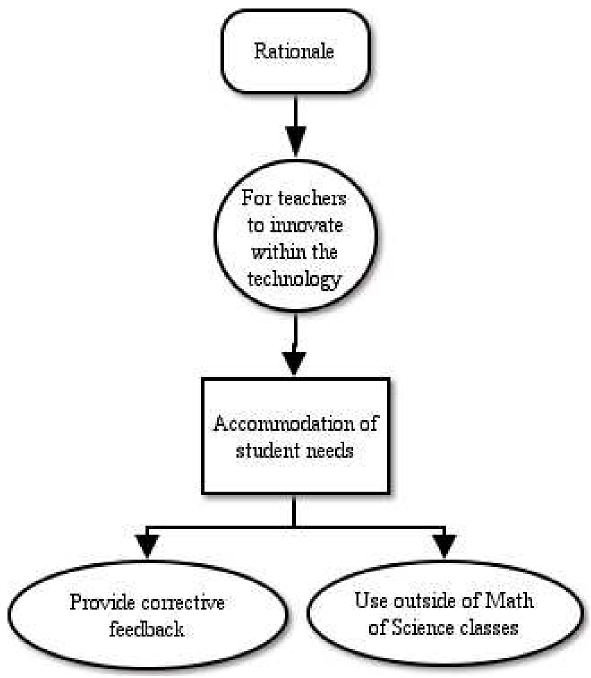


Figure 16. Rationale for innovation within a technology.

Narratives

The six participating teachers’ voices have been heard as they describe their experiences with the implementation of and use of EDU. It is also important to understand the viewpoint of other individuals in the district. The narratives that follow relate three separate viewpoints describing the personal perspective of the district curriculum specialist for mathematics, the district instructional technology consultant, and of the researcher.

District Curriculum Specialist for Mathematics

The Curriculum Specialist for Mathematics was consulted to provide insights concerning how the district decides what resources are required for teachers to use in their classrooms, what resources are supported in some manner and how support is provided. The specialist also discussed what if any resources are discouraged from use and why that may occur.

The district has developed a sequence of math objectives that are to be covered in each of two semesters. In essence, the district's requirements are very narrow in scope. Teachers are required to teach the objectives on the math card for the course they are teaching. While textbooks and the supporting teacher resources are provided, teachers are not required to use the text as their sole source for material to present in class. The district math cards are aligned with the district textbooks, thus teachers generally utilize the textbook as a primary resource for students to gather information and obtain practice problems. In addition to the district math card, graphing calculators are required in advanced math courses such as Advanced Algebra, Geometry II, and Calculus. TI 92 calculators and statistics software are also made available for use in an AP Statistics course.

The district has a replacement cycle for all curricular areas that occurs in approximate seven-year cycles. The district Math Department has a budget to address the need for replacing textbooks. As the math curriculum cycles around to its replacement year, new texts with supporting resource materials are selected, piloted, and implemented.

The math department also has a technology budget that is primarily used to replace classroom technology such as calculators. As funds are available, the district tries to create a balance of technology. Some of the district's high school math departments have been active in purchasing new technology for their building's math classrooms. In an effort to create an equitable technology base in each of the district's high schools, the district office may choose to use technology budget funds to place technology such as document cameras (Elmos), projectors, and interactive whiteboards (Promethean boards) in secondary math classrooms that do not have those resources.

While the district chooses to use district funds to provide technology hardware for its math classrooms, the district curriculum specialist is quick to point out, "For example the Elmo, there is no research that the use of technology increases student achievement. It is what the teacher does with the technology. Achievement is not related to increased use of technology, but what teachers do with technology." The specialist indicates a comparison of test scores from schools that have an abundance of technology to schools with limited technology for teacher use supports the technology-achievement premise.

Most of the district math department's technology funds go toward hardware. In general, the district does not provide funding for the purchase of software. The district specialist noted that more and more textbook companies are providing digital versions of their textbook. When the cost of the online digital text is included in the package for textbook replacement, the district will take advantage of the digital option as an enhancement to textbook resources. The specialist cautioned that usually the cost of securing a digital textbook is the same per student copy as it is for each hardback copy. However he anticipates that the digital versions of textbooks will become the norm in the future with students utilizing e-book readers instead of the heavier hardback texts of today.

Although funding is not normally allocated toward purchase of software, the district will provide support for use of software. This support comes in the form of district staff development courses. Staff members of this district are required to attend a prescribed number of staff development hours each year. The district math department provides a wide variety of staff development sessions to both support the need for hours as well as the need for training in the use of particular software, hardware, or other current math topics. All staff development sessions are paid for out of the math department budget.

All ideas for potential staff development sessions are filtered through department representatives. Math building liaisons and department heads are consulted about what types of staff development are most requested or needed by the math staff members. These topics are then offered as options for meeting the district's staff development requirements.

At this point in time the district math department does not require the use of a particular technology other than the use of graphing calculators and stats software in advanced math courses. The district does not have funding for non-required software technology. The district provides all training needed for teachers to utilize required technology. When technology is not required by the district, the district may choose to support technology by paying for training if the building liaisons and department heads indicate a need or desire of staff for such training.

For the district to become interested in adopting a software program for widespread district use in math classrooms, indications of a strong potential for math learning must be apparent. Evidence that the technology indeed did increase student learning would be imperative. There would have to be proof of achievement, proof that the software worked. Again the district specialist cautions that Mathmatica Policy Research (Dynarski et al., 2007) finds that neither independent nor individually based progress programs increase student learning.

This district specialist did not indicate any occurrences of actively restricting a particular technology by the district math department. Should there be a need to utilize the district's servers, then the Instructional Technology (IT) department would be a primary gatekeeper for server usage. IT largely decides what to allow or restrict based on system requirements and security issues. The district specialist was aware that there may have been some resistance from the IT department at the time EDU was being actively promoted by district math teachers and math department leaders.

District Instructional Technology Consultant

The primary function of the district's Instructional Technology Department (IT) is foundational in nature. The department's first priority is to create a network system that allows every building, department or curricular area, staff member and student to be connected and able to access needed materials and information to perform their respective duties. It becomes very much like a super-highway system of cyber connectivity.

There are several foundational areas. The network includes wired and wireless connections for all computers in the district, servers used for specific tasks, a voice over IP phone system, and security measures to protect the system. The IP system utilizes computer resources for distributing and receiving telephone calls. Servers are dedicated to handle specific applications such as email, web services, and student services. Security of the network and its components is a high priority and achieved by a wide range of strategies designed to provide the correct level of security required by each network need. Firewalls, encryption, and web filtering are some examples of how the district chooses to maintain a secure foundational network.

A secondary function of the IT department is to facilitate the shift in philosophy from one computer per classroom to one computer per teacher. The district is currently implementing that philosophy. In addition to making computers and laptops accessible to teachers, the department also invests in some periphery items such as projectors and smart boards.

In a pyramid of technology, the base level begins with the foundation of essential systems: network, servers, etc. As the foundational needs are met, IT moves up the pyramid and uses resources to address hardware, software, staff development, and infusion into the classroom. The IT director concedes that while the goal is to move toward second order change in the use of technology, most district technology resources support first order change.

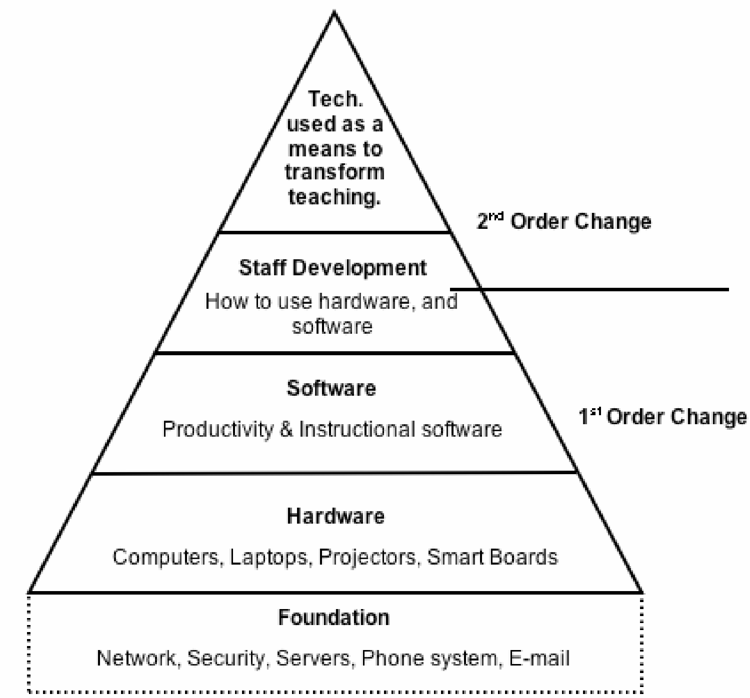


Figure 17. IT hierarchical pyramid.

Currently most educators are using or learning to use technology as a means to enhance their productivity and efficiency in completing necessary tasks associated with teaching. As more student-centered technology, such as smart boards with student response devices, is infused into classrooms, the influence on instruction has the potential to actually transform the way instruction is delivered. The IT director believes that the shift toward second order change will come as the ranks of educators swell with a new generation of technology users who view technology as natural and as common as paper and pencil.

It is no surprise that budgetary limitations are a barrier to increasing the district's technology resources. The IT director noted that in addition to providing necessary technology tools for classrooms, the district has also spent “lots of money to warm-up” the staff. Staff development requires a significant portion of the technology budget.

Technology is always changing or evolving. That evolution can also influence how technology is adopted, rejected, or put on hold. For example operating systems change more frequently than the district is able to embrace that change. The district chose to basically skip adopting the Vista operating system for their Windows machines and waited for the next operating system to appear before they made a wholesale operating system shift. Sometimes skipping a step may mean that the learning curve for staff increases. Resistance to change may slow technology changes.

The IT department’s philosophy is to align the procurement of technology to meet the needs for student achievement. The district looks for a new type of technology, such as new software, to provide evidence that it does affect student learning in some measurable way. Some business models view technology as a tool for automating education. The district’s IT director is adamant that rather than viewing technology as a tool for automating the teaching process; it is better to view technology as a tool for, in the IT director’s term, *infomating*. Technology is a means to provide depth to learning and allows students to learn at higher levels.

The district IT department shoulders the responsibility for training staff in the basic use of technology hardware and software applications. They have provided training on basic software programs such as Inspiration, Photoshop, and Microsoft Office or web resources such as netTrekker. The IT department’s goal is to integrate technology into curriculum areas and to enhance teaching. In essence they are nudging staff toward second-level change in the use of technology. The IT director recognizes that most staff, despite being given adequate training, have not made the transition from technology used primarily for productivity to technology used to change the way instruction occurs in the classroom.

Three steps describe how a district supported software or other technology is adopted. First, a need must be identified. For example, perhaps there is a particular software program that provides an alternative way to deliver Math instruction. Curricular experts would research and shop for potential solutions that meet the identified need. Those curricular experts would also consult with the IT department to identify several packages that have the most potential for district use. The IT department examines the potential product to determine if it will work with the technology infrastructure of the district. Of primary concern to the IT department is that the district remains connected to the network and productive within the network. It is important to protect the district servers from undue overload or stress. The IT department also evaluates the software to determine if it is user friendly and has good human interface and design built into it. The IT department's role is to advise and help analyze a product, thereby helping to assure that it will work well within the district. After being evaluated and adopted by the district, the staff must be trained in the software's use. Curriculum specialists are responsible for training their staff members in the use of programs that are curriculum specific.

The IT department wants to support new software and products that will be used by a reasonable portion of the staff. Use of a vetting process where a case is made for a product describing the product's usefulness and indicating there is a large enough audience interested in its use helps the district decide what technology will be of value and service to the district. If it appears that the usage base is small then district level support is not likely to occur. Another consideration is the vendor's role in upgrading the software or product. The level of ongoing vendor support will determine if the district is willing to invest time and money into use of the product. Without ongoing vendor support, the product is likely to not remain productive or trouble free, thus not worth the investment of time or money to adopt.

Several considerations are made when deciding to restrict a new technology. The district utilizes e-rate funding and must comply with Federal law, State law, and Board of Education policies concerning technology in education. Any technology or program that violates such laws and policies would not be considered for the district to use. If the considered product would depreciate the service provided by the IT department to the district, that product would not be a viable candidate for adoption. Streaming video is an example of how a product could affect district wide technology. Streaming overloads the system and creates an environment where essential district services are impaired.

Researcher

In the spring of 2004, I first heard mentioned that there might be training for the use of an online assessment tool that could be useful in the math classroom – something called *EDU*. My curiosity was piqued but nothing more was brought to my attention that spring. By late summer of 2005, an official staff development session was sponsored by the school district for teachers to receive cursorily training on the use of the EDU online program.

> EDU for Math Foundations (MGDE) and Math Interventions:
>
> EDU provides MPS teachers a computerized review of mathematics concepts that have been taught in the math classroom. Students receive immediate feedback for each problem worked and see detailed solutions. Teachers may construct assignments tied to specific course objectives by choosing randomly presented

> questions from an existing database. Teachers will understand the content available to the Foundations and Math Interventions databases and construct assignments to meet specified math objectives. (district publication, 2005)

A similar staff development session was available for teachers of Algebra and Extended Algebra.

I attended that staff development session along with approximately 28 other district teachers. I was intrigued with the idea that our math students would be able to receive extensive opportunities to practice and ultimately master many of the math objectives in their math course. An additional staff development opportunity was offered about a month later at one of the high schools. This time the emphasis was to learn how to enroll students in the program and also to learn a little bit about editing questions in the database and modify them to meet the needs of an individual classroom. Several other teachers from my building attended both EDU sessions. Due to our expressed interest, Mr. Fleming, the session presenter, offered to come to our building and give us additional training in the use of EDU and modifying problems in the database. We had five teachers from our building that attended that session.

The teachers were encouraged about the benefit that our students could derive from the use of EDU. As a group, we were especially interested in using EDU to relieve the burden of re-teaching and re-testing students who were unable to master an objective after completing a Chapter test. We hoped that our Math Intervention students would benefit greatly by the use of a program such as EDU.

At that time there were databases for the eighth grade textbook, the Math Foundations class, and for Math Intervention. Mr. Fleming promised to create a database of problems specific to the seventh grade textbook. He was true to his word. Before the end of the first quarter question banks appeared in a chapter-by-chapter sequence for teachers to use. By the end of the semester he had prepared database with almost all of the first semester objectives. Toward the end of this same semester, Mr. Fleming became involved in working with sixth grade teachers and creating a database for them to use. As a result EDU now boasted a fairly wide base of questions from which to choose for curriculum objectives. There were some gaps in the database problems but by borrowing from other course databases most objectives could be practiced and evaluated via EDU.

During the first year of EDU usage, the teachers at my school building explored how best to use it. I began to utilize EDU as a means to review prior to a Chapter test. On occasion I tried using it as an introduction to an objective. However my use of EDU found its most frequent use as a means to help students re-learn and re-master test objectives not mastered on the initial test. Three other teachers in my school building also began utilizing EDU in this manner. One teacher taught at all three levels in our middle school. This teacher introduced EDU to the sixth grade team, worked closely with me in developing practice sessions and re-tests at the seventh grade level, and also worked with one of the eighth grade teachers in establishing EDU’s use in eighth grade.

As we actively used EDU, we learned how to set up practice assignments. We learned what size of an assignment was most suitable to a class session. We found that patience is needed to work though unforeseen glitches. We learned that establishing usable practice and test session and saving them was the most efficient use of our teacher plan time. This allowed for rapid access by students. The first school year of using EDU whetted our appetite for consistent usage of EDU as a means to help student review in Math Intervention and for students to re-master objectives. We found that we desired to know more about how to edit questions in the databases so that the numbers were more suitable to our grade levels. However we did not have enough time to learn this skill during year one.

Toward the end of the second semester of this beginning year, we learned that Mr. Fleming would retire from the school system. We were concerned about the longevity of the EDU program. However Mr. Fleming graciously assured us that he would continue into the summer and update the databases. He also assured us that he would be available if we had any emergency questions. In reality we really lost a champion for the promotion EDU within the district. We wondered how the next school year would work out EDU-wise.

As I began year two of my experience with EDU, I found that indeed our EDU link still operated even though our *champion* was in retirement. I contacted Mr. Fleming and even though he was retired he was willing to help set up individual web links for each the four curricular areas at our middle school. This made for a more efficient management of the individual EDU courses. Soon the other seventh grade math teacher and I were utilizing EDU on a regular basis for re-teaching and re-mastery. The other teacher also taught Math Intervention classes and used it weekly as a way to review as well as re-master math objectives. We soon had a consistent rhythm of EDU usage.

With Mr. Fleming in retirement we never did gain expertise in modifying problems. A glitch that we were able to resolve was one of graphic files not showing up for some of the problems. The district had changed the way staff could store digital material from a system called Universal Locker to one called Docushare. Mr. Fleming's EDU files were still in the previous U-Locker site. Again he graciously worked to make sure that those files were moved to Docushare so that they would be able to be linked to the EDU databases.

Currently I am in year three of my usage of EDU. I continue to use EDU as a means to re-learn and re-master as well as doing some review sessions prior to regular tests. I still would like to learn more about modifying and writing problems for the database. One of our high school teachers is willing to work with me but I have not had the opportunity to set up a training session as of yet.

A sidebar to this EDU journey is that my school building is being closed this year. Teachers at my school who use EDU are wondering how this will affect usage next year, our fourth year in EDU. The site should still be accessible as the server is housed on the university campus and is not reliant on our school district for support. As the teachers who use EDU on a regular basis are dispersed through out the district, will this be the final straw for a program that showed such great promise for math students? Or will this be a means by which other teachers begin to also use EDU in their classrooms? The future is uncertain for EDU.

Chapter 5

Conclusions

Summary of Study

The purpose of this qualitative case study was to explore how a district responded to the opportunity to implement a new technology, specifically a software program called EDU. Data collection was conducted by interviewing six teachers and three district leaders. Each individual had the opportunity to contribute their viewpoints concerning the implementation of technology within the district.

The teachers provided their perspective as the actual implementers of EDU. They discussed how they became aware of EDU, what prompted them to use the application, the ups and downs of implementing the software, and their reasons to continue or discontinue using EDU. The teachers also described student encounters with the software. Narratives from district figures shed light on the philosophies and priorities of those who have administrative authority in the district. In addition the influence of a teacher leader on implementation of technology was explored.

The grand tour question guiding this study was, *How does a district respond to the opportunity to implement a new technology?* To understand the implementing teacher's viewpoint participating teachers were asked to consider their journey or process of incorporating a new technology, EDU, into their teaching repertoire.

This study is of interest because the district did not mandate the innovation under study; rather it was a grassroots implementation movement. Candid conversations of each teacher were recorded, transcribed, and analyzed. The recollections and opinions of these teachers are given voice in this study. As a result, this study relates a personalized view describing how a district responds to innovations.

The history of EDU implementation within one large urban public school district, MPS, spans a period of approximately eight to nine years. The initial spark of interest arose in Mr. Fleming who, at the time, was a teacher from the school district's instructional technology department. What began as an inquiry from Mr. Fleming about a new software developed on the university campus grew into a strong interest in seeing if this software had application in secondary education. Over the course of approximately three years, Mr. Fleming began to introduce MPS staff to EDU. This was accomplished through his own experimenting, as he said,

> Well it was worth the initial investment to conduct an experiment. And the experiment was the first classes that would go in and use it. So we didn't invest much up front. The initial investment, and initial visit to the computer lab and observations then immediately suggested that it was worth it.

Mr. Fleming became a participant in a university grant from NSF that included EDU as part of a summer math science endeavor. As part of that grant, Mr. Fleming was able to provide funding to pay several individuals for their time to write problems for the EDU database of questions.

During the second semester of the fourth year, the big *spark*, or *Ah-ha*, occurred. A class of low-achieving students in their last semester of high school was introduced to EDU. Their class used it almost every week during that semester. At the end of the semester, the students took a high-stakes exam used for demonstrating math knowledge needed for graduation. The pass rate in that semester's class surpassed the previous semester's pass rate by approximately128%.

As a result of the observance of significant increase in student achievement, Mr. Fleming became determined to bring EDU to a wider teacher audience than had been previously possible. This would have been about five years after he had first heard about EDU. He arranged training for staff through district staff development sessions and also held smaller training sessions at individual school buildings. EDU sites were set up at each middle school and groups of teachers began to investigate using EDU.

At the end of that year, Mr. Fleming chose to retire from the school district. Use of EDU during the next school year declined significantly despite the surge of training, EDU setups in buildings, and teacher exploration in the year just prior to his retirement. A district champion was neither recruited nor encouraged to take his place. With Mr. Fleming's retirement communication through out the district concerning EDU came to a halt. Some teachers at other schools who had used EDU the first year were under the impression that with Mr. Fleming's retirement EDU also retired. Mr. Loflin commented, "I really kind of felt like it was something that was gone. I didn't know if it was available anymore." A responder to the initial survey echoed Mr. Loflin by writing; "I thought that with Mr. Fleming gone the program for Math sort of died." The loss of the champion for EDU in effect retarded the growth of EDU. Only those educators who had used it extensively in their own classrooms were continuing to use it after Mr. Fleming's retirement.

Teachers and the Implementation Process

Teachers are open to new technological resources that may benefit student learning. Teachers are also open to resources that may reduce their teaching workload helping them be more efficient. EDU seemed to be a technology that held promise to do both. Its rise within the school district began at about the same time that the district was beginning to focus on mastery of math objectives as an important way to prepare students for success in Algebra and succeeding high school mathematics courses. EDU appeared to be a way to facilitate re-teaching, re-learning, and re-testing needs. It also appeared to be a resource that would add variety for classes with extended two-hour blocked schedules.

The participants in this case study described their information gathering as brief and mostly informal. Some attended formal staff development sessions and others learned how to use EDU through colleagues. The real training occurred in computer labs with students. Teachers who managed to establish a type of routine with EDU tended to be the teachers who were most satisfied with the web-based software program. They managed to use the program for a longer period of time. Common routines included once-a-week reviews in the computer lab, end of chapter or chapter reviews, or on-going practice for re-mastery and sometimes taking re-mastery tests. Some teachers used EDU during a core mathematics class time or during a math intervention period. Some teachers used EDU after school for students needing practice for re-mastery.

Regardless of how a teacher learned about EDU and the basics of using it, each participant regarded EDU leadership as integral for their continued interest and use. Mr. Fleming primarily demonstrated leadership throughout the district. He was viewed as the organizer and facilitator of the web-based program. In some instances one or more individuals were viewed as leaders within a particular building. If a building advocate for the program did not arise, EDU tended to fall into disuse in that building. At Mr. Fleming's retirement, a district level replacement never emerged. As Mr. Fleming commented, “It’s just been a very bumpy road. One reason for it there isn’t a Mr. Williams or me or somebody that is assigned to make it happen, to provide the support structure, to be the champion of it. You know, you always have to ask who’s the champion. If there isn’t a champion; it’s probably not going to happen. It’s not easy for it to happen.”

Table 1

Relationship of Interventions on Implementation

Affect of Interventions on Implementation	Leadership	Software	Students	District
+	Champion for the innovation at district level &/or at building level. Collaboration/ communication among colleagues.	Reduces cognitive load. Provides a path toward mastery. Efficient for teachers.	Positive attitudes about going to the computer lab. Independent learning. Observed student achievement (MGDE & re-mastery).	Did not officially reject the program. Provided time for training at staff development sessions.
–	Anti-champion at district level &/or at building level. Champion retires.	Glitches in the software. Host server not within the district.	Frustration with assignment problems. Frustration with how start using program.	No official support of the program. Question of EDU’s appropriate use.

EDU’s story within this district seemed to succumb to the fickle nature of many educational new ideas or innovations. Without encouragement from the district the metaphorical flow of oxygen to the flame came to a halt. The only wisps of encouragement came intrinsically from within small groups working collaboratively to use EDU within individual buildings or rogue teachers who continue to use EDU regardless of external influences. As long as they have access to EDU via the web, these groups of teachers seem to persevere.

Discussion: Technology in the Math Classroom

This study did not set out to prove Sweller's work on feedback and worked examples (Sweller, 1988, 1990, 2008; Sweller & Cooper, 1985). But this study does support his work. Feedback integrated with a worked example, aids in reducing cognitive load. An individual is only able to actively think about five to seven chunks of information at a time. When a student is learning new mathematical concepts and procedures, a worked example serves as a way to off load information to the printed page or screen. Thus allowing the student to think about the problem as well as to observe a correct solution.

Participating teachers recognized EDU's capability of not only giving students feedback as to whether their solution was correct but also providing a step-by-step example showing how to arrive at the correct answer. Mr. Fleming believed that the work done in MPS expanded that facet of the software to a greater extent than other users of EDU. Mr. Fleming states,

> We understood that better than all of higher ed that uses it, and we spent twice as much time on the feedback as we did on the questions because to show every step of the solution took time. But we felt it was worth it. That was the glimpse that I saw early on where we could tap into that and do it better than it was being done at that point in time.

When processing new or novel information, human beings are only able to consider a limited number of chunks at a time. Educators are cautioned never to ignore that fact. Precluding information stored in long term memory, learners must resort to randomly selecting a solution strategy, applying it, and checking to see if they are correct (Sweller, 2008, p. 33)

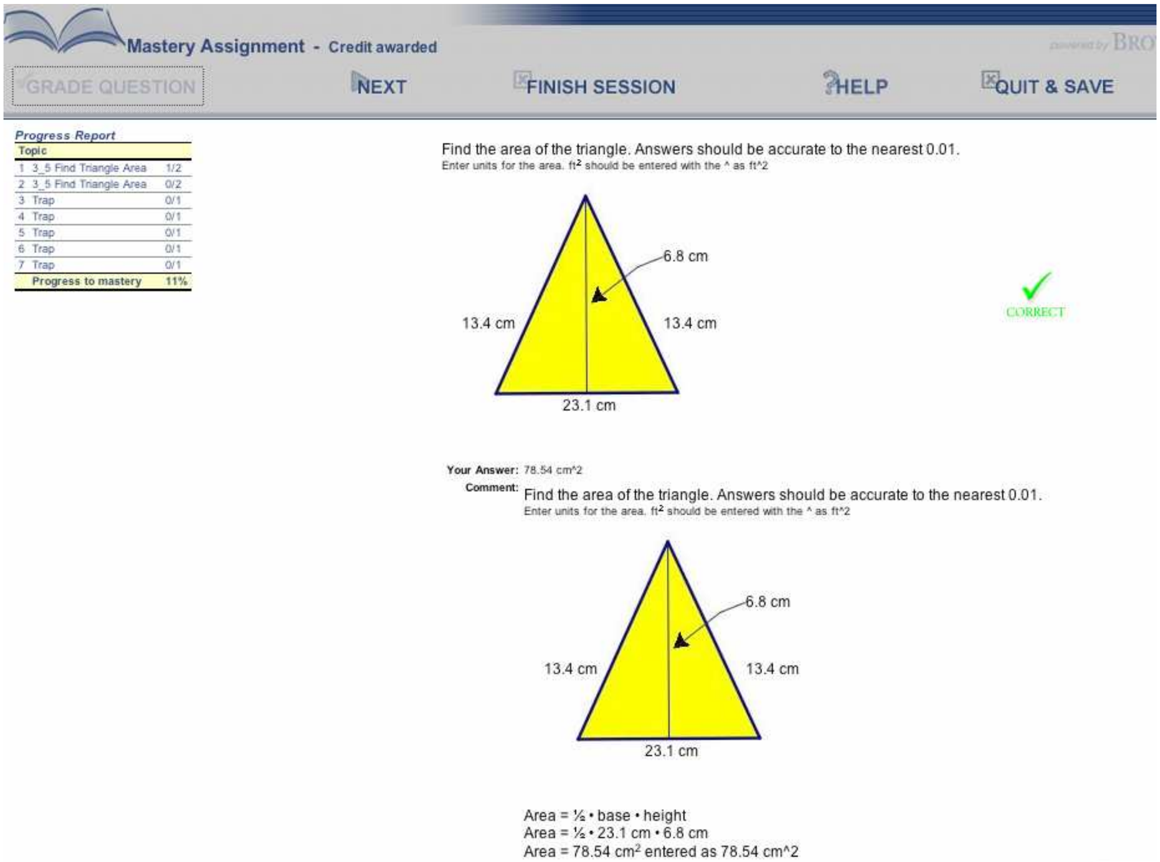


Figure 18. Example of corrective feedback when student answer is correct.

When mathematics teachers assign problem after problem without a guided example, students have no recourse but to cycle through what Sweller calls the randomness as genesis principle. However providing a worked example to the students as they work through problems allows the students to borrow a strategy from the example and apply that strategy to the next problem. This results in more efficient learning.

"Given a choice, always show learners how to do something rather than have them attempt to re-invent the wheel" (Sweller, 2008, p. 34).

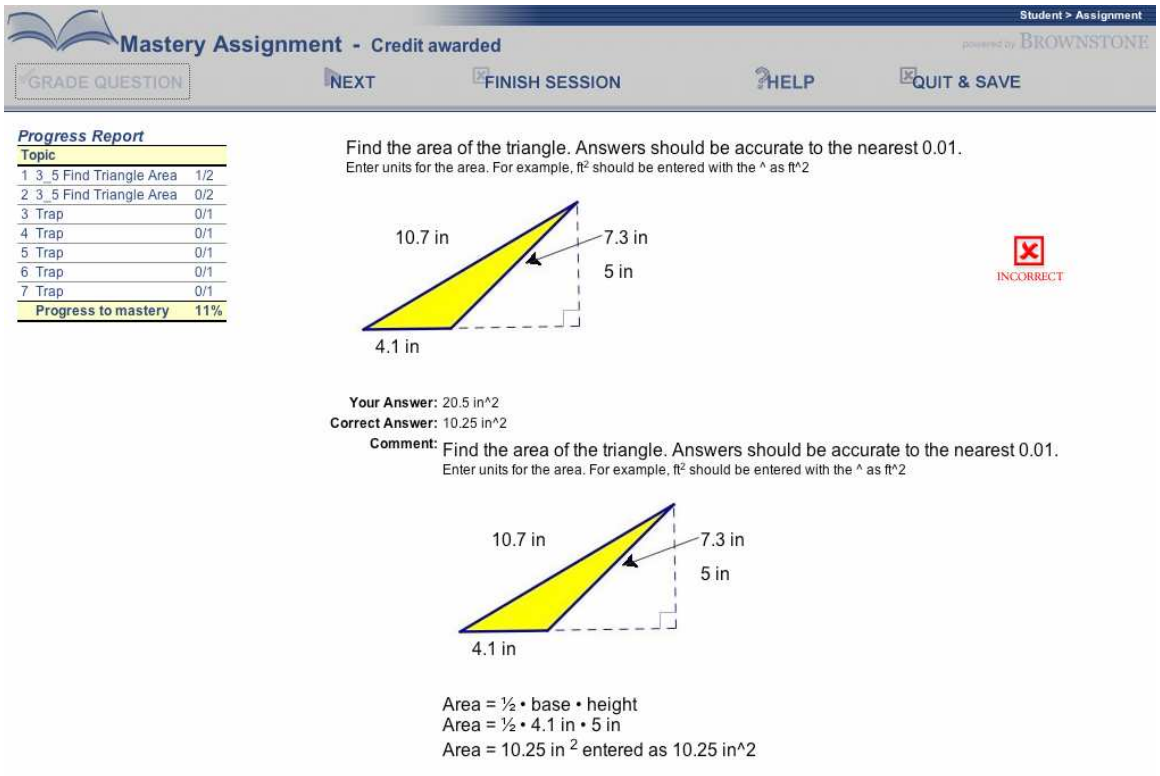


Figure 19. Example of corrective feedback when a student answer is incorrect.

The teachers participating in this study found Sweller's recommendations were actively demonstrated as students worked through EDU assignments. Students were able to move through assigned problems at their own pace, study examples if needed, borrow needed strategies, and move on to the next problem. The use of instructional applications that provide corrective feedback appear to facilitate a more efficient learning environment for students.

Worked examples can be provided in formats other than technology. However a software program, such as EDU, that produces a multitude of different problems coupled with worked solutions seems to be advantageous for students. Students are provided with a varied practice opportunity as they progress from working a new or novel problem to working a problem that is becoming mastered.

A converse to the usefulness of worked examples for novices is the decline in usefulness as learners become adept at working a particular problem. Requiring a student to study a worked example may be redundant for a student who understands and applies strategies correctly to a given problem. Redundancy increases cognitive load for that student (Kalyuga et al., 2001). Use of software that allows students to control their pace, provides the opportunity for students to self-regulate how long they dwell on feedback when using software that integrates worked examples with the feedback. This alleviates the redundancy for the more expert student while allowing students, who are still learning, as much time as they need to study the examples.

Mastery based software such as EDU allows the teacher to create a learning environment where pacing is controlled. When mastery is required mathematics students are not able to move on to new material until they have successfully answered the type of problem assigned. This assures that the student has a solid grasp of the basics necessary for solving more difficult problems in succeeding assignments. EDU has demonstrated the power of random number generation when selecting mastery software for mathematics students. A program with random number generated problems creates a virtually unlimited number of problems in a particular format of an equation or expression. Mastery lessons further ensure that redundancy is avoided. Practice on a particular problem type halts when the student has met a prescribed standard of proficiency.

Discussion: Technology Implementation Implications

Rogers (2003) identifies three conditions under which individuals in an organization make a decision to adopt an innovation. When people in authority roles make a decision to adopt an innovation, the individual has no choice but to do as required. Sometimes the individuals within an organization make a decision to adopt an innovation by consensus. The group makes the decision. Sometimes, such as for the educators in this case study, an individual may act on their own and adopt or not adopt, as they desire.

The district's curriculum specialist in MPS emphasized that the number of district requirements mathematics teachers are required to follow are, in essence, relatively few, albeit broad in scope. Teachers must follow the prescribed curriculum for the course being taught. The district identifies objectives that are to be taught by teachers and mastered by students. Textbooks are provided that teachers utilize as a primary teaching resource. That being said, the rest of what a teacher does in his or her classroom is a choice that he or she makes in relative autonomy. Some examples of what a teacher has full control over are how to present lessons, prepare for tests, what to select as teaching aids, and how to use technology in the classroom. While this district does not mandate use of technology in most mathematics classes, the influence of the district office does affect the optional decisions teachers make.

Most of the teacher participants in this case study indicated that they lacked knowledge needed to utilize EDU to as full an extent as they felt was possible. In two instances lack of knowledge stopped implementation prior to or at the end of a short trial period. Teachers repeatedly expressed that they needed to know more about how to do customizing of questions in the software's question banks. There were practical reasons that the teachers did not move to the level of problem writer or editor. The foremost reason was the retirement of Mr. Fleming, the district champion, before detailed training in question writing could occur.

The teachers in this case study identified reasons for deciding to take time to implement an optional technological innovation. Four primary reasons emerged from the teacher interviews. They acknowledge that leadership is important for implementation. Observing academic benefits for low-achieving students is a strong reason to implement an instructional application. A technology having features that alleviate cognitive load and that help teachers be more efficient cause teachers to want to implement and continue to use the application. The presence of district interventions that are supportive in nature, rather than being construed as restrictive, are conducive to teachers investing their time working with new applications.

Three perspectives were apparent in this case study: teacher perspective, district champion perspective, and the perspective of district leaders.

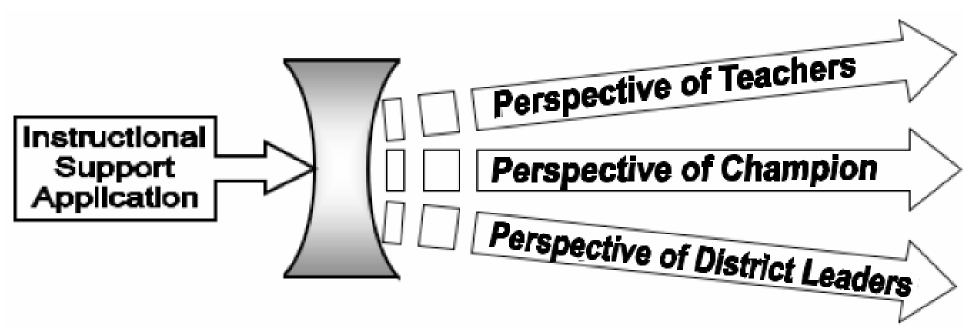


Figure 20. Diverging perspectives.

Each perspective began with the potential implementation of a promising instructional application. The perspectives or perceptions of the teachers, champion for the innovation, and district leaders diverged much like the manner in which light diverges as it passes through a concave lens. Mr. Fleming, the champion saw EDU's potential for affecting the learning of low achieving students. He saw it as a tool that could be transformational for low achieving students in the district. He hoped it would be accepted district wide. The mathematics teachers saw EDU as another tool for their collection of strategies. Their viewpoint of the application centered on how the application fit with their teaching style, how it met student needs, and how it fit within district constraints. The district leaders viewed EDU as just another option for teachers but took an aloof stance and did not choose to actively support or encourage its use. The district took a non-committal standpoint or a take-it-or-leave-it position concerning the application.

Lessons learned from this study are important for school leaders, department chairs, department liaisons, team leaders, and district officials to understand.

Lesson 1: Teachers need leaders or champions to be visible to those teachers desiring adopting a technological innovation. Teachers need arenas conducive to conversation about ways in which technology is being used in classrooms and how students' learning is affected.

Lesson 2: Teachers need access to software that helps teachers relieve cognitive load and at the same time increase teacher efficiency.

Lesson 3: Teachers need support at all levels.

Implications for Future Research

The district's curriculum specialist does not view technology as a way to increase student learning. He commented, "For example, the Elmo, there is no research that the use of technology increases student achievement. It is what the teacher does with the technology. Achievement is not related to increased use of technology, but what teachers do with technology." The specialist indicates that there is support for the technology-achievement premise when test scores from schools that have an abundance of technology for teacher use are compared to test scores from schools with more limited technology for teacher use.

This district's math department has a clearly functional view of technology as it pertains to use in the classroom. Funds are appropriated for purchase of new hardware technology, in an effort to maintain a semblance of technical equity between the six high schools. However purchasing software is not normally a part of the budget. The district specialist maintains that there is no direct link between technology and student achievement. His statement was supported by a U.S. Department of Education report (Dynarski et al., 2007) that indicated there was no significant change in student learning when technology software was used in sixth grade or Algebra classes. The district specialist asserts that particular study supports his philosophy that it is not technology, but what a teacher does with technology that increases student learning.

A year later the National Mathematics Advisory Panel (2008) reported that a generally positive effect on student achievement was shown when computer assisted instruction was used in Algebra classrooms. The advisory panel

> recommends that high-quality computer assisted instruction (CAI) drill and practice, implemented with fidelity, be considered as a useful tool in developing

> students' automaticity (i.e., fast, accurate, and effortless performance on computation), freeing working memory so that attention can be directed to the more complicated aspects of complex tasks. (National Mathematics Advisory Panel, 2008, p. 51)

It is apparent from these two very different reports concerning the effectiveness of technology in the mathematics classroom that further research is indicated. Educators need to have a better understanding of how appropriate mathematics technology may affect mathematics students' achievement. Educators need to understand what types of technology, both hardware and software, do increase student learning.

It is also of interest to investigate the methods, strategies, and applications that a teacher chooses to use when implementing technology as a means to assist in teaching mathematics. More studies, both quantitative and qualitative, will deepen our understanding of the effectiveness of technology in mathematics curriculums.

Final Conclusions

Implementing a new technology in a grassroots, optional-decision environment is fraught with perils unless there is some type of support at the district level. Consistent leadership within buildings and at the district level is crucial in the implementation process. Teachers can be persistent in the use of technology when there is some network of support. Even peer-to-peer collaboration can be enough to enable individuals to continue working with the technology.

For the teachers in this urban district that would like to continue their use of EDU the future is not bright. The EDU software was hosted on the university's server. It was understood that if the university ever migrated away from EDU to it's more commercial version, Maple T.A., that the district had the option to move EDU to the district server. At this point there is no indication that EDU will be hosted on the district's server.

Without a positive intervention from the district office, they will most likely not be able to continue EDU’s use.

This case study is one researcher’s encounter with a unique case. Through this study I was able to capture a glimpse of EDU’s beginning sparks, its momentary bright flame, and then its fall into disuse by many in the district. This study allowed teachers to give voice to their perceptions, observations, successes and disappointments.

Recall the boy and his flint and steel. The fire did not emerge without a shower of sparks and an appropriate continuous supply of oxygen. Flint and steel is indeed an apt metaphor for the implementation of an instructional application called EDU.

References

Block, J. (1973). Teachers, teaching, and mastery learning. *Today's Education*, *62*(7), 30-37.

Bloom, B. (1979). A conversation with Benjamin Bloom. Interview by Ron Brandt. *Educational Leadership*, *37*(2), 157-169.

Brooks, D.; Schraw, G., & Crippen, K. (2005). Performance-related feedback: the hallmark of efficient instruction. *Journal of Chemical Education*, *82*(4), 641-644.

Bruning, R., Schraw, G., Norby, M., & Ronning, R. (2004). *Cognitive psychology and instruction* (4th ed.). Upper Saddle River, NJ: Pearson Education, Inc.

Carroll, J. B. (1963). A model of school learning. *Teachers College Record*, *64*, 723-733.

Clark, R. C., & Mayer, R. (2003). *e-Learning and the science of instruction.* San Francisco: Pfeiffer.

Clark, R., Nguyen, F., & Sweller, J. (2006). *Efficiency in learning; evidence-based guidelines to manage cognitive load.* San Francisco: Pfeiffer.

Cuban, L. (2001). *Oversold & underused: computers in the classroom*, Cambridge, MA: Harvard University Press.

Dynarski, M., Agodini, R., Heaviside, S., Novak, T., Carey, N., Campuzano, L., et al. (2007). *Effectiveness of reading and mathematics software products: Findings from the first student cohort*, NCEE 2007-4005. Washington, DC: U.S. Department of Education, Institute of Education Sciences.

Gamoran, A., & Hannigan, E. (2000). Algebra for everyone? Benefits of college-preparatory mathematics for students with diverse abilities in early secondary school, *Educational Evaluation and Policy Analysis*, *22*(3), 241-254.

Garbin, C., Bradley, M., & Mason, B. (2002, November). *Evaluating alternative types of web-based activities in a research methods and data analysis laboratory.* Summary paper presented at the meeting of the Society for computers in Psychology, Kansas, MO.

Goldberg, M., & Harvey, J. (1983). *A Nation at Risk: The Report of the National Commission on Excellence in Education*. Phi Delta Kappan. 65(1), 14-18.

Kalyuga, S., Chandler, P., Tuovinen, J., & Sweller, J. (2001). When problem solving is superior to studying worked examples. *Journal of Educational Psychology*, *93*(4), 597-88.

Kulik, C., Kulik, J., & Bangert-Drowns, R. (1990). Effectiveness of mastery learning programs: a meta-analysis. *A Review of Educational Research*, *60*(2), 265-299.

Liu, X., PytlikZillig, L., Brunning, R. (2005), *EDU summary reports.* Retrieved June 8, 2009, from University of Nebraska – Lincoln. Web site: http://scimath.unl.edu/ EDU/asaanalysis.html

Ma, X. (2005). Early acceleration of students in mathematics: does it promote growth and stability of growth in achievement across mathematical areas? *Contemporary Educational Psychology*, *30*(4), 439-460.

Mayer, R., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist*, *38*(1), 43-52.

Midplains Public Schools, (2005). *Optional secondary mathematics professional development workshops.* District publication: Lincoln, NE.

Miles, M., & Huberman, A. (1994). *Qualitative data analysis: an expanded sourcebook* (2nd ed.). Thousand Oaks, CA: Sage.

Moreno, R. (2004). Decreasing cognitive load for novice students: effects of explanatory versus corrective feedback in discovery-based multimedia. *Instructional Science, 32*(1/2), 99-113.

Morrison, G., Ross, S., & Kemp, J. (2001). *Designing effective instruction* (3rd ed.). New York: John Wiley & Sons, Inc.

Motamedi, V., & Sumrall, W. (2000). Mastery learning and contemporary issues in education. *Action in Teacher Education*, *22*(1), 32-42.

National Center for Educational Statistics. (1995). *Trends in international mathematics and science study*, Retrieved June30, 2009, from http://nces.ed.gov/timss/

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics. (1995). *Assessment standards for school mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics. (2000). *Principles and Standards for School Mathematics.* Reston, VA: Author.

National Council of Teachers of Mathematics. (2008). *The role of technology in the teaching and learning of mathematics: a position of the national council of teachers of mathematics.* Retrieved June 8, 2009, from National Council of Teachers of Mathematics. Web site: http://www.nctm.org/about/content.aspx?id=14233

National Council of Teachers of Mathematics. Commission on Teaching Standards for School Mathematics. (1991). *Professional standards for teaching mathematics.* Reston, VA: Author.

National Mathematics Advisory Panel. (2008). *Foundations for success: The final report* *of the National Mathematics Advisory Panel*. Washington, DC: U.S. Department of Education.

Oakes, J., Gamoran, A., & Page, P. (1992). Curriculum differentiation: opportunities, outcomes, and meanings. In P. Jackson (Ed.), *Handbook of research on curriculum* (pp. 570-608). New York: Macmillan.

Oppenheimer, T. (2003). *The flickering mind: The false promise of technology in the classroom and how learning can be saved.* New York: Random House.

Paas, F., & Van Merriënboer, J. (1994). Variability of worked examples and transfer of geometrical problem-solving skill: a cognitive load approach. *Journal of Educational Psychology*, *86*(1), 122-133.

Pawley, D., Ayres, P., Cooper, M., & Sweller, J. (2005). Translating words into equations: A cognitive load theory approach. *Educational Psychology*, *25*(1), 75-97.

Riley, R. (1997). In math and college-going, middle school makes all the difference. *Middle School Journal*, *29*(2), 3-7.

Ritchie, D., & Thorkildsen, R. (1994). Effects of accountability on students' achievement in mastery learning. *Journal of Educational Research*, *88*(2), 86-90.

Rogers, E. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.

Romberg, T. (1992). Problematic features of the school mathematics curriculum. In P. W. Jackson (Ed.), *Handbook of research on curriculum* (pp. 749-788). New York: Macmillan.

Senemoglu, N. (2001). Effects of enhancing behavior of students and use of feedback-corrective procedures. *The Journal of Educational Research*, *89*(1), 59-63.

Shirley, L. (2000). 20th-century mathematics: A brief review of the century. *Mathematics Teaching in the Middle School, 5*(5), 278-285.

Slavin, R. (1987). Mastery learning reconsidered. *Review of Educational Research, 57*(2), 175-213.

Smith, J. (1996). Does an extra year make any difference: The impact of early access to algebra on long-term gains in mathematics attainment. *Educational Evaluation and Policy Analysis*, *18*(32), 141-153.

Spradley, J. (1979). *The ethnographic interview*. New York: Holt, Rinehart, & Winston

Stake, R. (1995). *The art of case study research*. Thousand Oaks, CA: Sage.

Starr, L. (2003). Middle-school algebra: ready or not? *Education World.* Retrieved June 30, 2009, from http://www.education-world.com/a_curr/curr147.shtml

Stoll, C. (1995). *Silicon snake oil.* New York: Anchor Books Doubleday.

Sweller, J. (1988). Cognitive load during problem solving: effects on learning. *Cognitive Science: A Multidisciplinary Journal*, *12*(2), 257-285.

Sweller, J. (1990). Cognitive processes and instruction procedures. *Australian Journal of Education*, *34*(2), 125-30.

Sweller, J. (2008). Cognitive load theory and the use of educational technology. *Educational Technology, 48*(1), 32-35.

Sweller, J., & Cooper, G. (1985). The use of worked examples as a substitute for problem solving in learning algebra. *Cognition & Instruction*, *2*(1), 59-89.

Van Merriënboer, J, & Ayers, P. (2005). Research on cognitive load theory and its design implication for e-learning. *Educational Research and Development*, *53*(3), 5-13.

Vockell, E., & Mihail, T. (1993). Principles behind computerized instruction for students with exceptionalities. *Teaching Exceptional Children*, *25*(3), 38-43.

Appendix A

Preliminary Survey

Preliminary Survey

1) Name: ____

2) Building: ______________________________________

3) Course(s) taught: ____

____

____

4) Have you used EDU in your classroom? YES NO

5) If you answered YES to #4, please indicate how long you have used EDU.

<1 yr 1 yr 2 yr 3 yr >3yr

6) If you answered NO to #4, are you planning on starting use of EDU during the 07-08 school year? YES NO

7) Have you attended any staff development sessions on EDU? YES NO

8) If you have any questions about this study, please record below.

Appendix B

Telephone / E-mail Script

Telephone / E-mail Script

Hello,
I am conducting a case study on the teacher's experiences and perception of using EDU in their teaching. I am asking if you would consider participating in this study and volunteer your perceptions and thoughts related to your experiences with EDU.

The study investigates how teachers perceive an innovation and their experiences implementing the innovation. This case study will look at how mathematics teachers implemented a technological innovation within their classroom and teaching. The participants for this study will be chosen from teachers from a large, urban school district who have participated in staff development training on the innovation. This study will be conducted over the course of the next five months and will be conducted at sites convenient to the participant and interviewer.

There are no known risks or discomforts for participants who are offering their individual perceptions for this research.

Participation is voluntary and you are free to decide not to participate in this study or to withdraw at any time without adversely affecting your relationship with the investigators, the University of Nebraska or with the school district where you teach.

Participants may ask questions concerning this research and have those questions answered before agreeing to participate or throughout the study. Participants may call the principal investigator, Sarah Crose, at any time, school phone (402) 436-1211, or after school hours, (402) 202-3068 or the secondary investigator, Dr. David Fowler, office phone, (402) 472-3347. If you have any questions concerning your rights as a research subject that have not been answered by the investigator or to report any concerns about the study, you may contact the University of Nebraska-Lincoln Institutional Review Board, telephone (402) 472-6965.

You will be asked to sign a formal letter of consent to participate in this study. A copy of the informed consent will be provided to you at the first interview.

Do you have any questions that I can answer at this time?

Appendix C

Interview Protocol #1

Interview Protocol #1

(Formative Phase: Knowledge, Persuasion, Decision)

- Tell me about your teaching experience to date.
    - How many years have you been teaching.
    - What is your level of education?
- Tell me about your level of experience with technology.
- Describe your beginning experiences with EDU.
    - Describe how you became aware of EDU.
    - When did you start using EDU?
    - What prompted you to start using EDU?
    - What training did you receive?

Appendix D

Interview Protocol #2

Interview Protocol #2

(Implementation Phase)

- Describe how you have implemented EDU into your classroom/teaching.
    - Describe your purpose for using EDU in your classroom and/or in your teaching.
    - Concerning you the teacher, describe your level of satisfaction about working with and using EDU.
    - Describe your level of satisfaction about working with and using EDU with your students.
- Tell me what you know about how EDU leadership formed and became shaped in the district and your building.
    - Describe EDU leadership within the district.
    - Describe EDU leadership within your building.
    - Describe how questions and other communication about EDU are facilitated.

Appendix E

Interview Protocol #3

Interview Protocol #3

Interview (Confirmation Phase and follow-up)

- Describe your perceptions of EDU use in your classroom.
  - Describe how EDU maximizes or minimizes your teaching time?
  - Describe how EDU has affected the way you teach.
  - Describe how EDU has affected the way your students learn.
  - Describe how EDU has affected your students’ success in mathematics.
- What ideas do you have for using EDU in the future?
  - If you could make changes in EDU, what would those changes be?

Appendix F

Informed Consent Document

Informed Consent Document

Identification of Project:
Secondary School Math Teachers and the Implementation of EDU

Purpose of the Research:
The purpose of this study will be to examine how teachers have incorporated EDU into their teaching practices as well as their perceptions about how EDU has impacted their teaching. Participants for this study are selected from math teachers who attended staff development training on the use of EDU. Each participant must be older than 19.

Procedures:
Participation in this study will consist of completing a series of three semi-structured interviews where you will be asked about your perceptions of incorporating EDU into your teaching. Individual interviews will be conducted throughout a four-month period. Interviews will take place at a district building convenient to the participant and researcher. A follow-up phone call or e-mail might also be included during the research period. The estimated amount of time for you to complete this research project is approximately 3 hours.

Risks:
There are no known risks or discomforts for participants who are offering their perceptions and insights about incorporating a new software program.

Benefits:
The information from this study will be interesting to the participant and to individuals desiring to better understand the dynamics of volunteer efforts in incorporating software.

Confidentiality
Participants will be audio taped and the recordings transcribed. The tape recordings will be destroyed immediately after each transcription is completed and the transcribed notes will be stored for two years in a locked cabinet in the investigator's home. After two years the transcribed notes will be destroyed. Data from this study will be reported in a dissertation. Any references to individuals will be safe guarded by the use of pseudonyms.

Opportunity to Ask Questions:
Participants may ask questions concerning this research and have those questions answered before agreeing to participate or throughout the study. Participants may call the principal investigator, Sarah Crose, at any time, school phone (402) 436-1211, or after school hours, (402) 202-3068 or the secondary investigator, Dr. David Fowler, office phone, (402) 472-3347. If you have any questions concerning your rights as a research subject that have not been answered by the investigator or to report any concerns about the study, you may contact the University of Nebraska-Lincoln Institutional Review Board, telephone (402) 472-6965.

Freedom to Withdraw:
Participation is voluntary and you are free to decide not to participate in this study or to withdraw at any time without adversely affecting your relationship with the investigators, the University of Nebraska or with the school district where you teach.

Consent, Right to Receive a Copy:
You are voluntarily making a decision whether or not to participate in this research study. Your signature certifies that you have decided to participate having read and understood the information presented. You will be given a copy of this consent form to keep.

Signature of Subject:

______________________________________ ____________________

Signature of Research Participant Date

Name and phone number of investigators:

Sarah L. Crose, MA, Principal Investigator Cell: (402) 202-3068
David Fowler, Ph. D. Secondary Investigator Office: (402) 472-3347