UNIVERSITY OF OKLAHOMA

GRADUATE COLLEGE

MATHEMATICS IN A UBIQUITOUS COMPUTING ENVIRONMENT: COMMUNICATION, ROLES, AND SENSE MAKING

A Dissertation

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

Doctor of Philosophy

By

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Norman, Oklahoma
2003

UMI Number: 3096337

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MATHEMATICS IN A UBIQUITOUS
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COMMUNICATION, ROLES, AND SENSE MAKING

A Dissertation APPROVED FOR THE
DEPARTMENT OF INSTTRUCTIONAL LEADERSHIP AND ACADEMIC
CURRICULUM

BY

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ACKNOWLEDGMENTS

I want to thank, first and foremost, the work of my chair, M. Jayne Fleener. She has been a patient reader, a constant encourager, and a careful editor. This dissertation would not have been completed without her help. Furthermore, I would like to thank my committee members, Amy C. Bradshaw, Barbara A. Greene, Linda J. McKinney, and Anne M. Reynolds for their guidance and support.

I would like to thank my family. Mike, ever the encourager who has built my confidence for 34 years and convinced me to pursue the dream; Laura, the loving, pragmatic and disciplined one who helped to build the vision; Casey, who has always believed in me; Bill, who is a patient and loving encourager; and Boomer, who was always by my side, or in my lap, as I read and wrote. They have all loved me, sacrificed for me, and supported me through the years as I pursued the dream. I appreciate them and love them for always being there for me.

Finally, I want to thank God for sustaining me and giving me the strength and wisdom to fulfill this dream. May He continue to bless me and allow me to give honor and glory to Him.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

ABSTRACT

This study examined how students used technology in a ubiquitous computer environment to communicate with their college mathematics professor and to each other, to understand how the role of the professor and relationships between the students and the professor changed as the technology was integrated, and how student participation with the electronic communications contributed to their sense making of mathematics. By providing descriptive detail of the students' reflective responses to e-journal prompts, I hoped to provide information that might assist other teachers as they struggle to enhance communication and understand student conceptual sense making while offering insights into a more dynamic curriculum with communications, meaning, and inquiry more centrally located. Three guiding questions focused the study:

1. How do the communication patterns evolve as electronic technology is integrated in the mathematics courses?
2. How do the roles and relationships among students and faculty change as technology is integrated?
3. How does participation with electronic communications contribute to students' sense making of mathematics?

The study found e-mail and e-journals provided opportunities to give individualized feedback to students and to extend the classroom conversation, but also enabled interactions that were not occurring in the classroom. This extension of the classroom dialogue provided new opportunities for students to think through issues that would not have been addressed in the classroom. E-mail and e-journals

permitted a diverse set of conceptual topics to be discussed in depth. While e-journals may have promoted student learning through student reflections, the e-journals provided the professor with important insights in the complexity of students' meaning making processes.

In conclusion, e-mail served as a conversational and instructional tool for a college mathematics class. E-mails provided the students a conversational tool in which they were able to converse with the professor about problems in or out of class, check about homework assignments, or just talk. As an instructional tool, e-mails allowed the professor to discuss students' conceptual problems. E-mail also provided the professor with an administrative tool in which changes in class times, assignments, or other organizational needs could be sent. E-journals provided an avenue for students to write as they reflected upon conceptual understanding and participated in the discourse community of the class, bridging the discourse community of mathematics. Additionally, the study supports the assertion that students' writing provides a starting place for change as teachers reflect upon how their students learn and think about mathematics.

CHAPTER ONE

INTRODUCTION

The World Wide Web has just begun to have an impact on our lives. Youth of today are growing up digitally (Brown, 2000). Youth multiprocess information, listen to music, talk on the phone, and use the computer, all at the same time. The web provides huge opportunities for educators to drive the chaotic transformation occurring in the world and in education.

First accessible in 1991, the World Wide Web took just seven years to become a part of the daily lives of 25% of Americans (Milken, 1998). This societal shift in such a short period of time is even more extraordinary when you consider the speed of change for other revolutionary inventions. Household electricity took 46 years to reach 25% of the U.S. population; the telephone took 35 years; the television, 26 years; the personal computer, 16 years; and the cell phone, 13 years. Information and communications technology has moved into every aspect of our lives in a short period of time. We communicate with others and retrieve information differently than we did just a few short years ago.

Manasian (2003) believes that while the Internet and its related technologies are capable of transforming society, the revolution has just begun. He predicts that technologies will change almost "every aspect of our lives—private, social, cultural, economic, and political. In some areas, the changes may be marginal, but in most they will be profound, and unprecedented. . . . New electronic technologies deal with the very essence of human society: communication between people" (p. 5). Social changes will be much more far-reaching and happen much faster than any changes in the past because of the breakneck pace of the technologies that are driving them. Manasian further argues the new electronic technologies will be as pervasive and ubiquitous as electricity. Many of the social and political choices that drive the changes for our future are impossible to predict, including whether the changes will be good or bad.

While Internet usage has continued to grow, many dotcoms have failed and telecommunications companies are struggling with close to $1 trillion of debt (Manasian, 2003). There is still reason to predict that the Internet revolution will resume and accelerate since the underlying technologies exhibit no signs of slowing down. Moore's law (the power of a computer chip will double about every 18 months) continues to be true since its beginnings in 1965. Due to recent breakthroughs in molecular electronics, it is believed that Moore's law will continue to be applied for another 50 years (Manasian, 2003). The speed at which the computer chip is increasing in power propels the growth of the Internet.

The Internet is growing logarithmically and globally. The number of worldwide net users has grown from 26 million in 1995 to over 459 million in 2001 (NUA cited in Bradshaw, 2001). Net users now number well over 500 million worldwide (Cetron & Davies, 2003). This is incredibly significant when you understand that the projected world population for June of 2003 is around 6.3 billion people (U.S. Census Bureau, 2003). Forecasts are placing the number of Internet users between 709 million and 946 million by 2005 (Cetron & Davies, 2003). While

Americans made up 42% of the total Internet-using population in the year 2000, the percentage had dropped to less than 37% in 2003.

Predictions for the future

What is ahead for the future of education and training for our society? Some of the predictions of Cetron and Davies (2003) include:

- Rapid changes in the job market and work-related technologies will necessitate increased training for virtually every worker.
- In the next 10 years, close to 10 million jobs will open up for professionals, executives, and technicians in the highly skilled service occupations.
- Schools will train both children and adults around the clock. The academic day will stretch to seven hours for children; adults will use much of their remaining free time to prepare for their next job.
- In the United States, education is moving rapidly to the Internet, as small, rural grammar and high schools supplement their curricula with material from larger institutions, while universities increasingly market their programs to distant students.
- Even small businesses must learn to see employee training as an investment rather than an expense. Motorola estimates that it reaps $30 in profits for each dollar it spends on training.

> Both management and employees must get used to the idea of lifelong learning. It will become a significant part of work life at all levels. . . . As the digital divide is erased and minority and low-income households buy computers and log onto the Internet, groups now disadvantaged will be increasingly able to educate and train

themselves for high-tech careers. (Trends in Labor Force and Work Section, ¶3-11).

Societal needs for student use of technology

In order to prepare students to meet the challenges of the new millennium, educational institutions are undergoing a struggle with decisions regarding function and direction. While reform and restructure has been ongoing, a major shock to the nation came in 1983 with the publication of *A Nation at Risk*, from the National Commission on Excellence in Education. Almost a decade later, America 2000, the educational reform plan of former President George Bush, followed. In 1994, the Clinton Administration revised America 2000 by adding points on teacher education and parental involvement and renaming it Goals 2000. In 2003, the Department of Education website describes the latest effort at educational reform:

> On January 8, 2002, President Bush signed into law the *No Child Left Behind Act of 2001*. The Act is the most sweeping reform of the Elementary and Secondary Education Act (ESEA) since ESEA was enacted in 1965. It redefines the federal role in K-12 education and will help close the achievement gap between disadvantaged and minority students and their peers. It is based on four basic principles: stronger accountability for results, increased flexibility and local control, expanded options for parents, and an emphasis on teaching methods that have been proven to work (U.S. Department of Education, 2003).

In this time of educational accountability and revenue shortfalls, educational administrators and policymakers are questioning the link between educational technology use and improved student achievement. Our society's growing dependence on technology for personal, social, and economic developments have a tremendous potential for providing incentives for use of technology in educational reform. While remembering that technology does not drive change, research needs to provide a basis for determining how technologies can support or impede student learning. Before we examine ways that technology may strengthen student learning, I would like to consider events in the field of mathematics that show how reform has provided a direction for examining educational technology.

Mathematics reform

The National Council of Teachers of Mathematics (NCTM) calls for reform in mathematics by establishing a Commission on Standards for School Mathematics. The commission oversaw the writing of *Curriculum and Evaluation Standards for School Mathematics* (NCTM, 1989) to answer the need for new goals for all schools. As industrialized countries made the transformation from an industrial to an information society, the aspects of mathematics "that need to be transmitted to students and the concepts and procedures they must master" (p. 3) must change for students to be self-fulfilled and productive citizens. The technological shift has become an economic reality in which the "pace of economic change is being accelerated by continued innovation in communications and computer technology" (p.3). The vision of NCTM includes "new social goals for education that include (1) mathematically literate workers, (2) lifelong learning, (3) opportunity for all, and (4) an informed electorate" (p.3).

After this first attempt by a professional organization to develop goals for educators, another commission was appointed by the directors of NCTM in 1995 to examine, evaluate, revise, and update the existing NCTM *Standards* of 1989. This document, *Principles and Standards for School Mathematics* (NCTM, 2000), reflects input and influence from many difference sources, including the National Research Council.

Six principles for school mathematics are addressed as overarching themes in NCTM's vision guiding educators seeking high-quality mathematics education. Two important principles for this study are Equity and Technology. These two principles are especially critical as we consider how technologies change and define culture.

Equity

Equity does not mean that all students receive identical instruction, but that all efforts should be made to encourage access and attainment for all students. Technology can assist in achieving equity and must be accessible to all students. Technological tools and environments provide access to opportunities for all students to explore complex problems and mathematical ideas, furnish structured tutorials to students needing additional instruction and practice on skills, or link students in rural communities to instructional opportunities or intellectual resources not readily available in their locales. All students must have the opportunities to use technology in appropriate ways so that they have contact with interesting and important mathematical ideas. "Access to technology must not become yet another dimension of educational inequity" (NCTM, 2000, p. 14).

The technology principle

One of the overarching themes included in the six principles for school mathematics is one regarding the use of technology. With the invention of handheld calculators in the early 1970's, the personal computer in the 1980's and the World Wide Web in the 1990's, there has been a revolution of immense proportion in which mathematics education is being re-created and re-developed. As research informs us, we recognize a need for change in which we question what mathematics students should learn and how they can best learn.

Proponents argue that technology is an essential tool in the teaching and learning of mathematics. Electronic technologies can support student learning in all areas of mathematics. Tools of technology allow students to concentrate on problem solving, reasoning, decision-making, and reflection. This study examined the role of communication and reflection as intertwined processes that assist students as they consolidate their thinking, requiring them to reflect on their work and clarify their thoughts about mathematical ideas (NCTM, 2000).

Role of technology in sense making in mathematics

Mathematical communications. As changes bring in new educational practices, the roles that new information and communication technologies play lead us to seek insights for efforts to expand and transform mathematics education in the information age. As Ansell and Park (2003) describe:

> The rapid growth of school technology infrastructure has led to increased availability and use of computers in schools. Most students now have access to computers and the Internet in their classrooms, nearly all students have access somewhere in their schools, and a majority of teachers report using computers or the Internet for instructional purposes. (p. 43)

Electronic communication tools are reshaping and expanding tutorial instruction and personal communications. As computer usage increases, increased use of e-mail interactions between faculty and students can take an extraordinary amount of the teacher's time (Hawisher & Pemberton, 1998).

Walther (1996) compared computer-mediated communications to face-to-face communications. In his study, he found that computer-mediated communicators, "unfettered by unwanted cues or multiple conversational demands, may engage in personal and relational optimization" (p. 23). Walther found several advantages in computer-mediated communications (CMC) over face-to-face communications. First, CMC is liberating. Information can be sent in almost no time over a distance and will remain there until needed. Second, CMC allows you to selectively minimize or maximize interpersonal effects. Third, CMC provides opportunities to communicate as desired, an "impulse that seems to be inherently human yet may be more easily enacted via technology" (p. 33). There may be several other advantages of electronic communications over face-to-face communications. E-mail may allow mathematics students who fear one-on-one conversations with their professor an avenue in which to express their thoughts and to compose what they want to say. Having the opportunity to compose their thoughts may be of particular significance to students whose first language is not English (Langsam & Yancey, 1998). E-mail can not only provide communication with the teacher, but may facilitate an environment in which students can ask questions, clarify course information, and broach issues outside of the classroom. Sometimes posted office hours do not mesh with students' class schedules and e-mail communication may be easier than attempting to track down the professor. Because mathematics tends to be a more difficult subject for many students, technology use may allow for a more open avenue for communication.

Reflection. The use of e-journals as a tool for encouraging reflections on the learning process may be valuable for student sense making, especially as students develop more facility and comfort with and preference for using electronic tools to convey their thoughts and emotions. E-journals may allow students to practice communicating mathematics, but also stimulate their thinking as they think through their understanding and learning. Thinking about thinking allows the construction of mathematical objects to become a central activity. "All students can benefit from a better understanding of their image of themselves as learners, of their learning processes, and of how their present efforts connect to their future dreams and aspirations" (Wolffe, 1998, p. 280). Reflection becomes not only *a* central activity; it is *the* most important activity that is absolutely necessary for learning. Writing provides an opportunity for the process of reflection.

Explorations and information. Support for writing to learn a content area has been developing for more than a decade (Miller & England, 1989). Expository writing has been shown to be an effective tool for teaching mathematical problem solving (Bell & Bell, 1985; Countryman, 1992). Providing students with opportunities to become competent communicators of mathematics, able to describe their thinking processes clearly, may assist in development of students' sense making in mathematics. When students communicate mathematical information, they remember it, understand it, and are able to use it to uncover and discover even more information (Buschman, 1995).

With the extensive availability of technology in schools, word processing tools provide students with a fresh way to communicate their understanding in mathematics. As students write about their awareness of mathematical constructions they have made, a means can be formulated for providing feedback to students as well as evaluating students' submissions (Meel, 1999). E-journals encourage discourse between student and teacher in a timely fashion. As lines of communication are opened between the student and the professor, information as to common errors and misconceptions may be found quickly and corrected.

Kimmins and Bouldin (1996) describe four roles that technology can play in the teaching and learning of mathematics. Technology can assist in the development of mathematical concepts and skills, mathematical problem solving, mathematical reasoning, and mathematical communication. In the development of mathematical concepts and skills, technology may assist students in dealing with multiple representations, enhance their ability to visualize, provide opportunities to construct mathematical knowledge, and enhance opportunities for diagnosis, remediation, and evaluation. In the development of mathematical problem solving, technology may allow students to focus on the process of problem solving rather than the computational aspect, to solve realistic, interesting problems earlier than before possible, and to provide increased opportunities to develop mathematical modeling skills.

Changing curriculum and learning dynamics

Changes in how we communicate with technology and potentially how we learn because of technology may require not only changes in the curriculum but how we even think about curriculum. As Doll (1993) describes:

> The implications for a post-modern perspective for education and curriculum are enormous but by no means clear. How the sweeping changes affecting art, literature, mathematics, philosophy, political theory, science, and theology—changes questioning the basic epistemological and metaphysical assumptions in those fields—will play themselves out in education and curriculum is yet unknown. (p. 3)

Doll believes that a new understanding of educational order will surface, resulting in a new view of curriculum emphasizing self-organization, process, and recursive growth. Today's linear, sequential, easily quantifiable ordering system that has dominated education may surrender to a more complex, pluralistic, random network. "Such a complex network will, like life itself, always be in transition, in process. A network in process is a transformative network, continually emerging" (p. 3). Doll further describes the curriculum as changing from a fixed, predetermined, prescribed, "course to be run" to a "passage of personal transformation" (p. 4). The curriculum will be creative and transformative, combining the scientific with the aesthetic. In an attempt at defining post-modern curriculum, Doll defines curriculum in terms of process—"a process of development, dialogue, inquiry, transformation" (p. 13).

Extending these ideas, Fleener (2002) describes "curriculum dynamics" as the on-going, interactive, interconnected process of educational conversations through inquiry. Curriculum dynamics as inquiry may be supported by mathematical conversations and reflective activity and facilitated and supported by electronic communication networks. With the availability of technology, advances in electronic communications, availability of laptops and wireless networks, many universities are requiring all students to purchase and use computers for coursework.

Rationale for the Study

As information and communications technology transforms the world at an explosive speed, the educational system weighs its responsibilities and attempts to meet the challenges of the new technology. The purpose of this first-person classroom-based study was to explore the changes that evolved among students in a college algebra class as wireless laptop computers were integrated in their mathematics course and learning environment. The study aimed to provide insight into the communication patterns that evolved as the students used the new technology to communicate with their professor and each other, to understand how the role of the professor and relationships between the students and the professor changed as the technology was integrated, and how student participation with the electronic communications contributed to their sense making of mathematics. By providing descriptive detail of the students' reflective responses to e-journal prompts, I hoped to provide information that might assist other teachers as they struggle to enhance communication and understand student conceptual sense making while potentially offering insights into a more dynamic curriculum with communications, meaning, and inquiry more centrally located.

There is little research studying the impact of implementation of campus-wide laptop computer programs in post secondary mathematics classrooms on student communications. There have been some studies; Duke, for example, decided not to require freshmen entering in Fall 2002 to own laptop computers because faculty members were not ready to use the technology in their classrooms (The Chronicle of Higher Education, 2001). As of November 2001, there were over 100 colleges and universities in North America (Canada and the U.S.) that have reported the implementation of a laptop program (Brown, 2001). Though laptop programs are now available at more and more colleges and universities, there is little research on how the laptop computers are influencing learning in the classroom, specifically the mathematics classroom.

Benefits and drawbacks exist in laptop programs (The Node Learning Technologies Network, 1999; Kontos, 2001; Healey, 1999, Rockman ET Al, 1997). Five benefits derived from laptop programs have a direct influence on learning in the classroom. First, there is equity in access to information. All students have equal access to information at all times, anywhere. There is no longer the gap between the students who have computer access and those who do not. Second, projects by students participating in laptop programs tend to be more sophisticated with respect to technological use than projects by students not participating in these kinds of programs. Third, professors find that activities are easier to design because all students have the same hardware and software. Fourth, educational issues are the focus for discussions relating to teaching and learning instead of issues of technology use. Fifth, students appear to be more enthusiastic about learning. "What students really love is the nomadic mobility. Students like to work in weird, different places" (Node Learning Technologies Network, 1999, p.7). Holleque's study (as cited in Node Learning Technologies Network, 1999) found that students believe their laptop computer experience will increase their career marketability when they graduate.

Laptop programs also face obstacles (The Node Learning Technologies Network, 1999; Kontos, 2001; Healey, 1999, Rockman ET Al, 1997). First, faculty workload is increased. Developing new applications for courses to include the use of the new technologies requires more time for the faculty to create and maintain. Students are able to cover almost twice as much material as they would in a normal semester, forcing faculty to spend more time in preparation for teaching. Communicating with students through e-mail also tends to be more time consuming.

Second, problems may be created with classroom management. Network use, on-line chatting, and computer-game playing may distract students from learning activities in the classroom. Third, students may find it difficult to adapt their learning style to fit the different student and faculty roles and relationships. Fourth, the use of laptop computers may increase the opportunities for students to cheat.

Many colleges and universities are considering the opportunities and difficulties surrounding the ubiquitous use of laptop computers on their campuses. The Node Learning Technologies Network (2001), an organization involved in research on mobile computing, states, "Most of the evidence of the impact of ubiquitous computing is still anecdotal, and inquiry into this area is affected by the lack of published research."

Context of the Study

The study took place in a small postsecondary church-affiliated university located in a suburban city in the Southwest Plains. I examined how learning and classroom instruction are impacted by ubiquitous computer usage during the initial year of an implementation project to provide laptops and Internet access to all students. The project involved the installation of mobile technology, including a wireless, campus-wide local area network (LAN) and notebook computers.

The study focused on how learning and classroom instruction were impacted in two college algebra classrooms by the campus-wide implementation of a mobile technology program. The guiding questions were:

1. How do the communication patterns evolve as electronic technology is integrated in the mathematics courses?

2. How do the roles and relationships among students and faculty change as technology is integrated?
3. How does participation with electronic communications contribute to students' sense making of mathematics?

Summary

In a ubiquitous, wireless computing environment, as technology impacts our world with its tremendous growth, use of laptops allows a flexible, accessible environment for students, faculty, and administration. With immediate, ubiquitous access to school and library resources the motto of "access to information anytime, anyplace" appears to be addressed. Equity among students is no longer at issue. Standardization of laptops and software allows all students to work on the same hardware and software with technical support for problems that may occur.

In the following chapter, I will provide an overview of the literature that discusses the growth of technology, its change on communication, and how current research relates technology and communication to various aspects of student learning.

CHAPTER TWO

BACKGROUND

In this chapter I give background information, explaining the use of technology to support mathematics sense making in a college classroom. First, I discuss the growth of technology and the impact on our communication paradigm. Second, I describe the use of mathematics journals for reflective writing to inform student conceptual understanding and foster communication. Third, I discuss how explorations with technology inform mathematical thinking through language. The potential of ubiquitous technology use to facilitate communications, develop relationships in the college mathematics classroom, and explore mathematical thinking will be presented in view of this literature review and as motivation for the current study.

Technology and Communication

There is much discussion about the contributions of computers to student learning. Many educators, parents, and society believe that access to computers will provide greater learning outcomes for students. Computer companies market software and hardware touting educational expectations that appeal so widely to parents wishing to insure a sound future for their children. Parents invest in computers to provide the best educational outcomes for their children. School systems set aside enormous budget amounts to build an electronic infrastructure to enhance the learning opportunities throughout their schools. The belief that the implementation of computer technology in education will greatly improve the learning of all students is a common conviction to many of these groups (Leikin & Zaslavsky, 1997).

Learning

As I began this study, I surveyed the literature linking technology and learning. I examined the immense amount of available information, repeatedly narrowing the focus of my search to a variety of terms relating technology, mathematics, and educational studies. After exploring the published literature addressing the impact of technology on mathematics learning, it was clear that there were several categories of studies. Some examined the impact of calculators and other non-computer technologies on learning. Others explored the use of computer tutorials and simulations. Because of the relative newness of Internet communications, fewer studies were found examining the impact of the Internet on students' mathematics learning. I will review related literature of Internet use on students' academic performance and social relations.

Use of technology has promised to motivate and engage students, to accelerate learning, to relate academics to the workplace, and to increase the economic worth of students. All of these promises are terribly attractive, but the question of concern is, does use of technology really answer the needs addressed? The Center for Applied Special Technology (CAST) performed a national study in fall 1996 to determine the role of online communications in schools. The study compared the work of 500 students in fourth and sixth grade classes in 7 urban school districts. Both groups of students involved in the study had computers and software; half of the students had online access and half did not. The results showed students with online access demonstrated significantly higher scores on measures of information management, communications, and presentation of ideas. Schacter (1999) reviewed research of the impact of technology on student learning and concluded that students with access to technology exhibited positive gains in achievement on researcher-constructed tests, standardized tests, and national tests. While Young (2001) believes research is largely composed of anecdotal stories of success and failure, he summarized the research by stating, "Technology and telecommunications, when used in combination with appropriate learning strategies, technology-proficient faculty and students, sufficient technology systems, and student access, can positively affect learning" (p. 45). Young concluded in his study that the question "is not *whether* [emphasis added] we should integrate technology into the curriculum but *how* [emphasis added] we can best integrate technology" (p. 52).

Healy (1999) cites The Powerful Tools for Schools report, an independent study of notebook programs conducted by Rockman *ET AL*, a nationally recognized education research firm from San Francisco. The study found that laptop computers assist students' problem-solving and critical thinking skills. Those students with access to notebooks utilized more information sources in research and used a greater variety of sources. One-third of the teachers believed that writing was the most improved skill with critical thinking next. The study also found that 87% of teachers believe access to computers has improved the quality of student work, with writing as the most improved academic area.

While proponents of computer technology are flaunting the positive effects of computer technology and learning, some are challenging the use of technology and demanding the reframing of education. Cummins and Sayers (1995) believe control and coercion is evident in schools. Control over textbooks and curriculum materials are designed to transmit the values deemed important by controlling factions of society. The continued failure of our schools to educate minority groups will continue until the top-down control over the learning process is altered to provide access to information through the Internet. This change would prohibit the guarantee that students learn only what is considered culturally or politically appropriate. Cummins and Sayers (1995) argue that we must "reframe education around critical inquiry and the collaborative generation of knowledge in such a way that the experience and cultural contributions of all students are valued" (p. 13). "We believe that the academic involvement participation of currently underachieving students can be enhanced dramatically by using tools such as the Internet in the service of collaborative critical inquiry" (p. 170).

Information revolution

Postman (1992) argued that his concerns with the computer have nothing to do with its efficiency as a teaching tool. The computer has altered our conception of learning. We need to know what ways this is happening and how it undermines the old ideas of schooling. "New technologies alter the structure of our interests: the things we think *about.* They alter the character of our symbols: the things we think *with*. And they alter the nature of community: the area in which thoughts develop" (p. 20). Introduction of a new technology does not merely add or subtract to our lives; it changes everything.

Innovations throughout the centuries have changed society completely. Postman (1992) described five stages of innovations in the information revolution. The first began with the invention of the printing press. The invention of the printing press created new sources of data collection, but also increased communication among scientists. Standardization of scientific discourse resulted, including the standardization of mathematical symbols and conversion from Roman to Arabic numerals. Ambiguity and error in texts, diagrams, and charts were reduced. In essence, "the press announced the advent of science, publicized it, encouraged it, and codified it" (p. 64). The information revolution began with an information explosion.

The second stage of the information revolution described by Postman (1992) began with the telegraph. The telegraph took information from being a local commodity to an entity that did not know time or space. Newspapers provided information from great distances quickly. The third stage of the information revolution began with the graphic revolution, characterized by the invention of the photograph and other symbolic images including prints, posters, drawings and advertisements. As telegraphs and photographs supplied instant information, the amount of information available through words and pictures grew exponentially. The fourth stage of the information revolution was the onset of broadcasting. The fifth stage was computer technology.

Each of the stages brought about new forms of information in exceptional amounts and increased speeds. Information was being generated at such great speeds and intensity that it had become a form of garbage, disconnected from theory, meaning, or purpose.

> The point to be stressed here is that any educational institution, if it is to function well in the management of information, must have a theory about its purpose and meaning, must have the means to give clear expression to its theory, and must do so, to a large extent, by excluding information. (Postman, 1992, p. 75)

Relationships

As I studied the literature examining the connections between computer technology and learning, I identified studies that examined the relationships that occurred as a result of the technology use. In a California study of teachers who used the Internet with their classes, Hemenway (2000), reported on the effects of Internet use on the teacher-student relationship. Interview results included statements that students have become the teacher to the teacher. Students see things from a different perspective than the teacher; they see things from a different viewpoint. Another teacher believes it is "kid-to-kid learning, almost individual instruction as they all learn at their own pace. . . . The locus of control has changed." "Students are highly, highly, highly engaged" (p. 115).

Research suggests socially oriented interactions may contribute to a more confidential relationship and a greater trust in sharing (Bonk & King, 1995; Mercer, 1995). Because communication within an Internet environment may be uninhibited and depersonalized, information exchange may occur at a faster rate and may enrich interpersonal and social relationships (Walther, 1996). A study by Wang, Laffey, and Poole (2001) found members of a collaborative team who had strong, personal, and social relationships contributed to an online team project in an unrestrained manner.

Members of the team felt unconstrained and more at ease to voice differing opinions and in challenging other team members' opinions in online discussions.

"Wireless computing is becoming an integral component of learning environments in higher education and in the world of work, particularly with the increasing number of 'laptop universities' and distributed-learning communities" (Gay, Stefanone, Martin, & Hembrooke, 2001, p. 257). While there is little research in the use of technology and its effects upon the shift in the communication paradigm, there are extensive amounts of literature revealing the impact of the computer upon learning. In light of this extensive research, we are able to assume that mobile and wireless computing could significantly alter the ways students learn, content of courses offered, learning-related practices, classroom dynamics, and relationships between faculty and students (Gay et al.)

Communication

Because of emphasis on mathematics communication found in the NCTM Standards (2000), many studies are now available examining communications found in the mathematics classroom. Few mathematics studies are available, however, that examine the electronic communications now accessible to students and professors through the Internet. Few would disagree that we communicate with others and retrieve information in a way so radically different than we did just a few short years ago. To evidence the shift in the communication paradigm, online classrooms are revolutionizing universities around the world. Virtual learning has altered the structure of education in which there are no classroom walls and in which students are discovering new ways to access information, solve problems, and communicate and collaborate with fellow students, faculty, and other experts (Johnston & Cooley, 2001). Students are able to communicate with professors and access information 24 hours a day, 7 days a week. Technology has shifted the communication paradigm; new methods must be used to take advantage of the Internet's effective and intriguing possibilities. Communications as a fundamental component to meaning making in mathematics will be problematized in the third section.

Reflective Writing

The intertwined nature of reflection and communication assists in the improvement of mathematical reasoning of students. "Writing in mathematics can . . . help students consolidate their thinking because it requires them to reflect on their work and clarify their thoughts about the ideas" (NCTM, 2000, p. 61). Mumme and Shepherd (1990) found that as students get used to writing they appreciate writing as a part of doing mathematics. Communication in the context of reflective writing is depicted as "transmission of thoughts" mediated by language whose function is the construction of models of student thinking (Sierpinska, 1998). Poet William Stafford (as cited in Connolly, 1989) wrote, "A writer is not so much someone who has something to say as he is someone who has found a process that will bring about new things he would not have thought of if he had not started to say them."

Conceptual understanding and sense making

A variety of researchers have reasoned that student journals can be a powerful methodology for assisting students in the learning of mathematics (Applebee, 1981; Connolly & Vilardi, 1989; Countryman, 1992; Meel, 1999; Pugalee, 2002). In the establishment of a dialogue with the teacher, journal writing can benefit students by requiring them to "think for themselves on paper, explore new ideas, solve difficult problems, express feelings, diagnose errors, and consider alternative solutions" (Rose, 1989, p. 25). The mere act of writing in mathematics is crucial in the development of curiosity and comprehension in the learner (Botstein, 1989).

Battista (1999) describes the relationships of abstraction, reflection, and learning. In scientific constructivists' explanations of learning, abstraction is the "fundamental mental mechanism by which new mathematical knowledge is generated" (p. 6). Abstraction is a process wherein the mind chooses, coordinates, mixes, and records in memory a grouping of mental items or acts that materialize. Understanding mathematics is more than abstraction, requiring reflection. Reflection is the conscious process of mentally rethinking and replaying experiences, actions, or mental processes and considering their results or how they are created. As these acts of reflection become abstracted, circularity begins in which the acts of reflection become the subject that is acted upon in future acts of reflection and abstraction. From this theory, meaningful mathematics learning emerges as a recursive cycle.

Connolly (1989) describes language as an expressive and reflective instrument through which we communicate what we have previously thought. The nature of written language, because of its slowness, forces us to be more self-aware and self-conscious of our senses and the details of our thoughts. The actual process that we go through in becoming more aware and conscious of ourselves, aids in the sense making needed for conceptual understanding. Writing requires inner speech to be compressed in order to make it understandable, consequently making a conscious structuring of a web of meaning (Pugalee, 2002). "Writing can be a powerful process for discovering meaning rather than just transcribing an idea that is in some sense waiting fully developed in the writer's mind" (Applebee, 1981, p. 100). In writing, as a way to express an idea or reveal subject-area knowledge, the process of putting problems down on paper and carrying through the steps helps to reveal an answer.

Wheatley (1992) describes the process of reflection as a "scheme of schemes" (p. 535). In reflection, students have "greater control over their thinking and can decide which of several paths to take, rather than simply being in the action" (p. 535). Encouraging students to justify a method of solution to an activity often encourages reflection. In this reflection, they dissociate themselves from the activity and make the activity an object to be examined. Wheatley further claims that it may be possible for students to be so busy that they fail to have time to reflect and thus do not learn. "(I)nstruction which has reflection as a primary component enables students to construct robust mathematical relationships" (p. 540).

Jurdak and Abu Zein (1998) found that journal writing resulted in cognitive benefits in mathematics achievement at the level of conceptual understanding, procedural knowledge, and mathematical communication, supporting a positive effect on overall mathematics achievement. However, they found journal writing failed to positively affect problem solving. They attributed this failure to the complex nature of problem solving, journal writing, or both. Journal writing failed to improve school mathematics achievement measured by performance on regular school mathematics tests. While students developed a positive attitude towards journal writing, their attitudes toward mathematics did not improve. In conclusion, the study found:

> [The] experience of journal writing was rewarding to students, teacher, researchers, and even to parents, some of whom visited the school to express

> their support for journal writing and to request its continuation in the school program. It was an enjoyable activity for students and a vehicle for learning and self-expression. It was also enjoyable to the teacher, for whom journal writing provided a window to how the students thought and felt. (p. 417)

Relationships

In addition to the potential of journals to facilitate academic connections, keeping journals in class encourages the building of relationships between teacher and students. As students build positive, comfortable relationships with teachers, attitudes, feelings, and anxiety towards mathematics may be affected. In a study by Meel (1999), journal writing had a positive affect upon student attitudes. Meel further describes the use of e-mail for submission of dialogue journals as being beneficial in sustaining personalization yet keeping the focus on the course mathematics. Tobias (1989) found that students who wrote about their past experiences in mathematics were able to move from "a paralyzing fear of mathematics back into the mathematics classroom. Getting students to write about their feelings and misconceptions would relieve their anxiety and help them unlearn models and techniques that were no longer useful to them. Eventually, they could approach the new with confidence" (p. 50).

Studies show that journals may aid in the building of an atmosphere in which the students and teacher become a community of learners (Gordon & Macinnis, 1993; Britton, 1990; Meel, 1999). "(S)tudents felt they could contribute ideas, make requests, or provide opinions" (Meel, 1999, p. 407). Journals involved students in their own learning process, synthesizing information, making them aware of what they do understand and don't understand, and examining their own learning styles and strengths (Talman, 1990; Meel, 1999). Informal writing "encourages students to struggle with new material, to let themselves wonder, speculate, and experiment with ideas" (Countryman, 1992, p. 88). As students write down their ideas and speculations, they explore questions that have been lurking in the deep, dark recesses of their minds; they begin to take control of their own learning. E-mail provides an innovative way to assist both student and professor in the exploration of ideas through journal writing. Students find that sending their writings to their professor through e-mail is easier; professors find the writings easier to read. Electronic communications such as e-mail are changing the way we work and learn.

Electronic Communications

Leslie (cited in Kirkley, Savery, & Grabner-Hagen, 1998, p. 210) touted researchers' findings that e-mail has "democratizing effects, citing substantial evidence that it flattens hierarchies, promotes teamwork, and increases involvement of peripheral workers within organizations." E-mail has become the most dominant form of communication in many universities and businesses, developing qualities more commonly associated with spoken language, and following the norms and behaviors of both text and conversation. While e-mail can have the immediacy of verbal communications, because messages are delivered within seconds, it often leads to frustration if a reply is not received promptly. Little research has been done in the evaluation of communications through e-mail. As in other computer communications, problems exist because of the lack of non-verbal cues found in face-to-face interactions. Absence of these cues makes it difficult for understanding the intent of the message, but does suppress "social conventions such as hierarchies" (p. 210) and personalities who may dominate in a classroom. Walther (1996) showed that though the impersonality of e-mail was due to a lack of nonverbal cues, the medium of e-mail merely slowed the nonverbal cues in their transmission. Interpersonal effects of e-mail participants may develop in proportion to the growth in the number of messages. While the lack of cues is problematic in a classroom environment, many students often seem to prefer E-mail contact to face-to-face interactions. This review of the literature, has examined the growth of technology and its impact on our communication paradigm and how the use of mathematics journals for reflective writing inform understanding and foster communication. As we consider the influence of technology and the communications found in reflective writing, we must consider the connections with mathematical thinking has with language as we search for meaning and understanding.

Technology, Mathematical Thinking, and Language

This section describes technology as it informs mathematical thinking through language, focusing on those studies grounded in poststructural and postmodern perspectives.

Language

Fleener (2002) depicts the search for meaning and understanding as a search of creation, rather than discovery. Following the path of Wittgenstein, meaning is articulated through language and our creative invention of ideas. "Definitions of words can only be understood in the history or context of their use rather than an appeal to some underlying meaning or fixed reality. Meanings evolve as use and context change" (p. 12). Meaning and understanding are the role of language as our perceptions and ideas are exposed through the language we use. "Language, as the river of meaning through which we swim, is the medium through which meaning is supported" (p. 13).

In an attempt at seeking understanding of embedded meanings in the language of students, Davis (1997) describes a perspective of listening as an interpretive framework. In his research involving an eight-grade classroom teacher, he suggests three teaching episodes that depict three categories of listening: Evaluative, interpretive, and hermeneutic. Examining the types of listening in which we participate may provide view of communication that allows us to understand and partake in language games, the on-going and evolving meaning structures embedded in our language (Fleener, Carter, & Reeder, in press).

Evaluative listening. Often, when teachers listen to their students' mathematical conversations, they are looking for correct answers. Unexpected or incorrect responses elicit correction. In this way, evaluative listening may be unreceptive to student input if the responses from students are not the sought for answers. This manner of evaluative listening may be suggestive of the teacher's concept of mathematics as being an established, consistent system of formal truths and that the teaching of mathematics is a process through which one proceeds without ambiguity. The teacher, the authority, is listening for the "correct" response before the lesson is continued along its planned course (Davis, 1997).

Interpretive listening. While evaluative listening may portray a teacher as following a script without modifications for classroom activities, interpretive listening involves a more flexible teacher role. Students must provide more elaborate answers to questions in class and often include a demonstration or explanation. Because of the nature of the interactions, the teacher may not anticipate answers and must be aware that the interactions may affect one another's thinking. Teachers must listen more carefully so that student communications can be thought about in different ways. Authority in the classroom remains with the teacher who has "defined her task in terms of converging on some sort of true or correct understanding of the concept at hand" (Davis, 1997, p. 365).

Hermeneutic listening. Davis (1997) describes hermeneutic listening as negotiated, participatory interactions with learners. There exists a dynamic interdependence between teacher and setting, "thought and action, knowledge and knower, self and other, individual and collective, rather than on autonomous constitution or construction" (p. 370). Learning becomes a social process with the teacher's role that "of participating, of interpreting, or transforming, of interrogating—in short, of listening" (p. 371). When we listen, we find meanings of words and learning occur within language games.

Language games

Fleener et al. (in press) describes Wittgenstein's use of language games not as an attempt at trying to capture the meaning of words or providing rules to follow, but by providing important insights for the complexity of meaning making. Wittgenstein's approach to meaning focused on seeing, experiencing, and feeling. "Key to understanding, seeing, experiencing, and feeling, according to Wittgenstein, was language. His language-games approach represents the linguistic turn in philosophy" (Fleener, 2002, p. 130).

Fleener (2002) describes "linguistic turn" as the shift in approach from an epistemological basis to focusing on studies of meaning and language use. "Meaning, Wittgenstein shows, is inextricably connected to context" (p. 131). Sfard (2000c) describes meaning by using a quoting a famous statement made by Wittgenstein: "The meaning of a word is its *use* in the language" (p. 46). While use in the language is restricted and not arbitrary, it is well defined by an infinitely complex set of rules and determined by discursive forms, which determines their meaning. Sfard further argues that while there is much agreement as to the importance of linguistic use, from the psychological point of view, meaning cannot be denoted through linguistic analysis alone. The experiential aspect of meaning includes imagery and emotions, among others.

> (U)nderstanding the parts of a whole, which is the kind of understanding we gain while analyzing use, does not translate automatically into an understanding of the whole. The collection of pieces is not enough to reconstruct the 'living creature,' this unique experience of 'seeing' a meaning of a symbol. (p. 47)

The postmodern narrative includes the logics of relationships, systems, and meanings. Fleener (2002) describes Wittgenstein's' philosophical approach for the exploration of language games:

> The logic of meaning is precisely the structure of relationships revealed through language use. Language games, like complex adaptive systems, are autonomous, self-producing, self-sustaining, and self-maintaining. They are also adaptive, evolving, changing, and transforming as contexts change. Language games therefore define their own boundaries and cannot be studied from outside the game itself. (p. 134)

The logics of postmodernism provide three different perspectives of the same thing. Meaning can be envisioned as it permeates all of the perspectives of the language games. This perspective of meaning places a greater responsibility on conversation, communication, and relationship in the classroom. The role of language as a meaning system likewise has implications for how learning and thinking are construed.

Mathematical thinking and communication

Consistent with the language-games approach, Vygotsky's emphasis on communicative public speech over inner private speech, Sfard (2000b) describes mathematical thinking this way:

> (T)he better we understand public discourse, the deeper will be our insight into the dialogue one leads with oneself. If one further agrees that thinking is nothing other than communication with oneself (not necessarily inner, and not necessarily verbal), then one must realize that investigating communication with others may be the best route to discovering the mechanisms of human thinking. From this conclusion, it follows that thinking is subordinated to, and informed by, the demands of communication. (p. 296)

This is a reversal in the priorities of thinking and communication. The proposal that the apparatus of thinking is somehow subordinate to that of communication is certainly not a trivial idea. Sfard states: "Instead of being merely helpful in the constructing and sharing the knowledge of preexisting mathematical objects, communication and its demands must now be regarded as the primary cause for their existence" (p. 297). Thus, Sfard is suggesting that thinking itself is a communicative process.

Sfard (2000b) describes thinking as dialogical in character. Like conversation between two people, thinking involves turn taking, the asking and giving of questions and answers, and the building of each new remark upon the previous one in such a way that all are interconnected in some way. The idea of communication can not be described appropriately as an exchange of meanings, as if meanings involved objects or things that can be moved or transferred from person to person. This perspective is contrary to traditional views of the relationship among meaning, communication and thinking. Reddy (1993) describes the concept of communication as an exchange of meanings by calling it the "conduit metaphor," coming from the idea of the transportation of material goods. The metaphor suggests that communication "transfers thought processes somehow bodily. Actually, no one receives anyone else's thoughts directly in their minds when they are using language" (p. 166). Because the metaphor has permeated our language so deeply, the idea of communication as being the transmission of some idea or thought is almost impossible to avoid. From the perspective of the inextricable relationship among meaning, communication, and thinking, there should be an increased emphasis on communications in the classroom.

Views of classroom communication

Sierpinska (1998) describes three views of classroom communication: Constructivist approach, sociocultural approach, and interactionism. In the constructivist approach, language is described as a symptom of thought. This symptom of thought allows the teacher or researcher to understand the student's thinking and reasoning. "If speech is an encoded thought, then communication means transmission of thoughts mediated by language. The hearer decodes the utterance of the speaker to reach to the thought. There is no warranty, however, that decoding is an inverse operation to encoding, hence the possibility of error and thereby, the theoretical impossibility of the transmission of thoughts" (p. 33).

In the sociohistorical approach, Sierpinska uses Vygotsky's idea of communication as a cultural fact. "Language is a cultural tool, a specifically human instrument of communication" (p. 42). Intellectual development in Vygotsky's sense is the development of concepts. The concepts, or meanings of words, are theoretical, emphasizing the discursive nature of knowledge. This ties "thinking and development to language and communication, and thus to culture, in a way that is more causal than contingent" (p. 43).

In the interactionist approach, language or discourse, seen as a social practice, has an important role. Mathematics is a discourse that is established through communication, a language seen from the perspective of pragmatism. Meanings of mathematical expressions are found only when they become a part of a mathematical discourse that a person shares with others. A symbol has meaning only when it is shared and is a part of a discourse. The discourse as a whole gives meaning to the parts, not the other way around. Knowledge emerges from shared discursive practices that develop in contexts, through applications, or through examples and problem solving (Sierpinska, 1998).

The shared discursive practices that are developed are part of Edwards and Mercer's (1993) definition of education: A communicative process consisting of "growth of shared mental contexts and terms of reference through which the various discourses of education . . . come to be intelligible to those who use them" (p. 63). The shared discourse uses mathematical language to communicate mathematical understandings and encourages student learning of new concepts. As students describe, explain, and illustrate their learning of new mathematical concepts, misconceptions can be identified and confronted. In addition, Silver, Kirkpatrick, and Schlesinger (1990) believe that the communicative process reminds students that they share in the learning that is taking place. In essence, educators who seek to encourage a search for mathematical meaning and understanding through discourse in the classroom must hermeneutically listen to their students as they seek to understand, see, experience, and feel. As they explore the meaning created through language games, they may better understand the students' mathematical thinking. With the shift in the communication paradigm, intriguing possibilities exist in new ways to communicate and explore meaning making electronically.

Use of technology

In such a technology-oriented age, though not all schools in the United States have Internet access, more and more schools are providing access to computers and e-mail facilities (Bradshaw, Bishop, Gens, Miller, & Rogers, 2002). While many studies exist in which communication and communication patterns in mathematics classrooms are studied, this study focuses on viewing communication as the nexus of relationships that are viewed as the patterns that connect. Healey (1999) described the rapid worldwide growth of computer notebook programs and believed that notebooks will become the classroom norm. "Clearly, there's value in providing educators and students with tools that are representative of the age in which they live, tools that enhance the skills of communication so that all students are ready to face the world of their future" (p. 17). In South Carolina, Gottfried and McFeely (1997) studied student use of laptop computers in and out of the classroom in a pilot program where 300 sixth-grade students were given laptop computers to use. They found the technology-rich classroom enriched and enhanced the students' lives, increasing student motivation and altering the learning environment. Gillespie (1998) describes a mathematics colleague's efforts at using e-mail. The colleague found that he could extend his office hours and boost student contact through invitations to e-mail him. Contact with students who were intimidated by face-to-face encounters in the office could be increased through e-mail communications. In addition, by sending messages and assignments through e-mail, he found that students could be lured into reading their e-mail, making them more likely to communicate with him.

Meel (1999) described a study in a college calculus classroom in which he used e-mail dialogue journals. Meel identified other effective electronic tools for communication, but felt that certain components were necessary for effectiveness. The means for communication must allow for private and spontaneous communications between professor and student. By-products of the communications must be easily archived, resource friendly, and supportive of the transmission of complex mathematical symbols. While e-mail satisfies the issue of privacy, other electronic tools such as chat rooms and bulletin boards do not. All three allow for spontaneous interaction and are resource friendly, but only e-mail and bulletin boards are easily archived. E-mail's inability to directly support mathematical symbols is a problem that can be avoided through word-processing programs, which chat rooms and bulletin boards cannot access without great difficulty.

Though few studies were found to support the use of technology as it informs mathematical thinking through language, it seems quite logical that in the technological era in which we live, electronic communications provide an effective and versatile opportunity to inform mathematical thinking through language.

Research Focus

Communication was the center of my study. While the growing use of technology may change our paradigm of communication, links between student thinking, learning, and language still inform us about the processes needed to engage teacher and students in self-regulated, constructive, and reflective activities. My study focused on the communication patterns that evolved as electronic technology was integrated into the college algebra class, the evolving roles and relationships among students and faculty as technology was integrated, and contributions of electronic technology to students' sense making of mathematics. The method for analysis is discussed in chapter three.

CHAPTER THREE

RESEARCH DESIGN AND METHOD OF INVESTIGATION

In this chapter, the research design and methodology used in the study will be discussed. The study took place in a small postsecondary church-affiliated university located in a suburban city in the Southwest Plains. I examined how learning and classroom instruction were impacted by ubiquitous computer usage during the initial year of an implementation project to provide laptops and Internet access to all students. The project involved the installation of mobile technology, including a wireless, campus-wide local area network (LAN) and notebook computers for every student and faculty in Fall 2001. Three guiding questions motivated the study:

1. How do the communication patterns evolve as electronic technology is integrated in the mathematics courses?
2. How do the roles and relationships among students and faculty change as technology is integrated?
3. How does participation with electronic communications contribute to students' sense making of mathematics?

Research Perspective

To assist in understanding the complex nature of constructed realities, qualitative researchers interact and talk with participants about their perceptions

(Glesne, 1999). From the interactionist perspective, I viewed the important role of language or discourse as a social practice (Sierpinska, 1998). As an interpretive, naturalist researcher, I assumed that my research dealt with multiple, socially constructed realities that are complex and inseparable into discrete variables. To accomplish the task of understanding and interpreting the interactions and constructions of the participants in a qualitative study, theory building was preceded by thick description. Denzin (1989) describes this thick description as going beyond simple reporting of an act but also one that "describes and probes the intentions, motives, meanings, context, situations, and circumstances of action" (p. 39). Thick description has two basic characteristics. First, it explores patterns within interactions that allow us to understand embedded meanings, actions, and feelings. Secondly, it is interpretive, capturing the hidden meanings the participants bring with them. Thick description makes an attempt at describing and interpreting the events occurring during an interaction.

To assist in building a thick description, the study gathered information from surveys of all participants, followed by two in-depth interviews of selected participants, weekly e-journal responses from all participants, and responses to queries on a discussion board. Meaning is embedded in the communications of the participants. Description provides the framework for interpretation. Denzin (1989) described the framework: "Thick interpretation interprets the interpretations that are present in the recorded experiences" (p. 159).

Facilitator Participant Observer

In this study, I acted as a facilitator participant observer. I was immersed in the setting-- the classroom--with the participants along with the research questions. I made the participants (my students) aware of the goals of the study and formally asked their permission to use information from their journals, discussion board responses, e-mails, or interviews. As participant observer, I also attempted to form relationships with the participants so that they were able to serve as both respondents and informants (Denzin, 1989). My role as participant observer allowed me to get to know and interact with the participants in the classroom as well as outside of the classroom through the use of the technology. Because I was a facilitator participant observer, I was able to make adaptations in the learning situations in the classroom and adjustments in data gathering as a result of information gathered from interactions with students. As a facilitator participant observer, I became an insider to the classroom-based research.

Classroom-based research

Conventional research on teaching looks *in at* teaching and learning. In this study, I examined teaching and learning *from the inside* (Ball, 2000). This first-person inquiry was different from other approaches in that it used the "position of the teacher to ground questions, structure analysis, and represent interpretation" (p. 365). Inside approaches to research blend the construction of practice with its analysis. This approach was able to suggest special perspectives of insight and understanding observed through the first-hand experience of the teacher. I was able to probe portions of the experiences of my students invisible to outsiders. First-person research provides the teacher's voice and perspective as a means to "legitimate perspectives of practice in the construction of knowledge about teaching" (p. 375).

Similarities exist between case study research and first-person classroom-based research. Ball (2000) describes two important features that are characteristic of first-person classroom-based research. First-person classroom-based researchers start with an issue and then design a framework in which to pursue it. "The issue with which they begin is at once theoretical and practical, rooted in everyday challenges of practice but also situated in a larger scholarly discourse, and they create a way to examine and develop that issue further" (p. 386). This study began with the issue of the impact of ubiquitous laptop use, rooted in the everyday challenge of learning in a college algebra classroom, situated within the discourse of communications as it informs learning. The design of the framework of the research did not proceed linearly, but was continually adjusted during the study. "First-person research offers the researcher a role in creating the phenomenon to be investigated coupled with the capacity to examine it from the inside, to learn that which is less visible" (p. 388).

Design Overview

To frame the research, I followed Tobin's (2000) interpretive research design within the classroom-based research perspective. While interpretive research recognizes its subjectivity, it does not adhere to the idea that everything is acceptable and that there are no standards. An interpretive researcher seeks to understand through "systematic activity focused on efforts to understand the interactions between participants in social settings in terms of the perspectives of the participants" (p. 488). Interpretive research requires ongoing interpretations that allow adaptive assumptions on which the design of the study is built. Principles of an emergent design that necessitates ongoing analysis and interpretation permitted the design of the study to adapt to changing events of the classroom. Interpretive research utilizes a variety of data sources in order to increase the credibility of what is being learned.

I studied the communication patterns that evolved through the use of electronic technology, the meanings and understandings apparent in the communications, and the effects the communication patterns had on the students' sense making. I explored the changing roles and relationships among the students and the faculty as electronic technology was integrated through the use of e-mail, discussion board, and journaling. I investigated the role of electronic communications in students' sense making of mathematics through the student interviews and students' e-journals.

Research Setting

I conducted my research at a small postsecondary church-affiliated university located in a suburban city in the Southwest Plains during the spring semester. The university had 51% male and 49% female students. Eight-four percent of the students were white, non-Hispanic; 7%, Black; 3%, American Indian or Alaskan Native; 2%, Asian, Pacific Islander; 2%, Hispanic; 3%, unknown. Seventy-one percent of the students lived in college-owned, operated, or affiliated housing.

The university launched a mobile computing program as part of a strategic initiative called the eCampus project in the fall of 2001.The eCampus project had as its vision to provide a personalized technology-enriched experience for students with anytime, anywhere access to all university constituents in order to:

- Enhance Student Learning.
- Extend Communications.
- Enable Student Services.
- Engage Campus Constituents.
- Encourage Information Literacy.
- Empower Students for the Future.
- Enhance [the university]'s Reputation (Oklahoma Christian University, 2001).

The university provided all students with identical IBM ThinkPad computers with full maintenance and hardware and software support. All students received basic skills training at the beginning of the first semester of the program with future training limited to freshmen and transfers. All college-owned, operated, or affiliated housing, campus offices, campus areas, and classrooms have wireless network nodes with sufficient bandwidth for all students to be online at once (Bolin, 2003). [See Appendix H for a copy of the document detailing the purposes for the program.]

All students enrolled in college algebra classes in the spring semester at the selected university were asked to participate in this study. Each class met for 50 minutes three times a week on Mondays, Wednesdays, and Fridays. The class, part of a sequence for elementary education, biology, and psychology majors, fulfilled a prerequisite for students taking Calculus and Introduction to Statistical Methods. While College Algebra was one of several classes that fulfill the mathematics general education requirements for many majors, the course was composed of a wide variety of majors. [See Appendix C for details.] The class was primarily composed of freshman and sophomore students: 57% of the two classes were freshman; 34%, sophomores; 6%, juniors; and 2%, seniors. While the overall percentage of females in the two classes was 60%, the morning class was composed of 48% females, with the afternoon class 71% females. Students scored a 23 or higher on their American

College Test (ACT) or had successfully completed Intermediate Mathematics before enrolling.

Selection of Participants

On the first day of classes students completed a survey about their background, attitudes toward and experiences with computers, and beliefs about mathematics. [See Appendix A for a copy of the survey and Appendix C for details of the survey results.] In addition, it also asked for volunteer participants for the in-depth interviews. From the initial population of 47 students, 12 students, 6 students from each class, were selected for in-depth study. This group was purposefully selected based on characteristic responses from the initial survey. Chapter 4 describes the selection process in greater detail. Although criteria evolved based on the kinds of responses submitted, there was an attempt to select students with varying interests, experiences, and beliefs about mathematics and technology use. These students were a convenience sample and were also selected as representative and/or extreme cases. An equal number of male and female students were chosen. Because of the homogeneity of the population, students were not selected based on ethnicity, race or ACT entrance scores.

Data Collection

Data collection began on the first day of the new semester at the selected university. Multiple methods were used to collect data to enhance the validity of the interpretive first-person classroom-based research study findings. On the first day of class, the study was described in as much detail as possible to both classes. Informed Consent forms and surveys were distributed to all students. [See Appendix F for a copy of the Informed Consent form.] The Informed Consent made sure the students were willing to allow the professor to use information from their journal entries and discussion board postings. Three students declined the invitation to participate in any form of the study described. All students, as a part of the regular coursework, were required to complete the surveys and e-journal submissions. Coursework, e-mail interactions, Blackboard submissions, surveys, interviews, and the researcher's field log were part of the data used for this study. Data collected from the three students who declined to participate was not used in the study. Data collection ended the week before final exams because of the time constraints. Interviews were scheduled and completed the week before final exams to avoid conflicts with student studying. A particular effort was made so that students separated their participation in the interview process from their grade in the class. While E-journals prompts were completed the week before final exams, other communication tools remained available for student use. Attempting to follow the participants after they left the university for the summer was not practical.

Primary Data Sources

Survey

A survey was issued and used to elicit student reactions to computer use in students' mathematics classes. All students completed surveys asking basic questions about their mathematics background, computer usage, expectations for the class, role of the teacher, and mathematics' practices. The survey was also used to help choose students for the in-depth interviews. [See Appendix A for a copy of the survey.]

Survey information regarding students' computer experience was useful in determining the amount and type of instruction students needed for computer communications with other students and with me. Little computer instruction was needed; all students except for one had experience in Microsoft Word; many students had at least minimal experience with Microsoft Excel; and most had experience with PowerPoint. All students were provided with training on use of Blackboard software in the fall semester. Freshmen and transfer students with less than 30 credit hours were required to enroll in a class called Freshmen Seminar to help them acclimate to college life. Other transfer students took an orientation class before their laptop computer was issued. The survey also asked for volunteer participants for the in-depth interviews.

Interviews

From the group of volunteers willing to participate in the interviews, 12 students, 6 students from each class, were selected based upon information given in the survey. These interviews occurred two times during the semester: once at the beginning, and once the week before dead-week (before the final exam). In order to have a variety of students, students were selected as either representative of the class or as an extreme case. Equal number of males and females were chosen. Because of the homogeneity of the population, students were not selected based on ethnicity, race or ACT entrance scores. [See Appendix F for sample interview questions.]

Initial interviews of the 12 participants provided more detailed information describing the students' expectations, fears, computer familiarity, mathematical understands, expectations of the roles of teacher and student, and previous experiences with mathematics in greater detail than the survey. Individual interviews probed and extended information and ideas evident from participation in class activities, assignments, and the survey. The final interview was used to clarify how the use of the laptop computer had contributed to the students' sense making in mathematics. The interviews also assisted in further clarifying the evolving roles and relationships among fellow students and me. Interviews were audio taped and transcribed.

E-Journals

During the semester-long study, participants submitted weekly journal entries in response to questions about their mathematical understandings and their attitudes and feelings about mathematics. Journal prompts were posted weekly on the Blackboard announcement page. All students were required to submit one journal entry each calendar week on or before 6 pm on Friday of each week. Journal entries were required to be complete thoughts and written in complete sentences; entries had to be a minimum of a half page in length. Submissions that did not fulfill the requirements were returned with a note from me asking for further clarification. Students were required to submit the responses by e-mail.

E-journal prompts consisted of two questions or sentences to which students responded. During the first week of classes, one prompt asked students to talk about themselves and their feelings about mathematics. The other prompt said, "If mathematics was a fruit, it would be a . . . because . . ." In the beginning, prompts were designed to encourage students to talk about their history with mathematics and to reflect upon their understanding of mathematical concepts. [See Appendix B for a listing of e-journal prompts and dates.]

Entries encouraged students to describe their frustrations, problems, and successes in the class and to discuss a mathematical concept being studied. Journal entries were used to assist in the identification of students' mathematical understandings and evolving communication patterns between students and me. Journal entries were archived for analysis.

Discussion Board/Virtual Chat

An on-line classroom delivery tool called Discussion Board, a part of Blackboard, was available for student and faculty usage. Discussion Board provided a forum for students to communicate and discuss topics online, further enhancing learning opportunities facilitated by the wireless laptop computers. Two different threads were available for discussion. One thread had a topic that encouraged students to discuss their understanding of the meaning of a phenomenon. Another thread was available for discussion of homework questions. While participation in the Discussion Board was encouraged, it was not required. Initially, I chose a time that I felt would be convenient to the students to hold virtual office hours. During the virtual office hours, I was available for discussion, questions, or any type of assistance a student might need. Initially, virtual office hours were held every Tuesday and Thursday evenings from 9-10:30 p.m. To reach out to students who were too shy to ask questions in the open forum provided by the Discussion Board, I also checked e-mail to help students privately with questions.

Students were encouraged to participate in discussions on the discussion board and to seek assistance with assignments from the teacher and other students through e-mail or the discussion board. [See Appendix E for Discussion Board prompts.] Discussion board postings and e-mail transmissions allowed communicative patterns to emerge. All communications from the participants were collected and archived for analysis.

Data Analysis

Analysis

Data analysis involves organizing what you have seen, heard, and read so that you can make sense of what you learned in the study (Glesne, 1999). For interpretive research, analysis consists of making a detailed description of the study and its setting (Creswell, 1998). Data collection and analysis ran concurrently for most of the time during the study, with the final stage of analysis beginning after data collection had ceased. Reflecting on the data, working to organize the data, and then understanding what the participants are trying to tell you begins when data collection begins.

Lofland and Lofland (1984) suggest the first and most important task in data analysis is the establishment of a filing system. Mundane files, for keeping track of people or documents, were made for all students enrolled in College Algebra. Informed consent forms, surveys, transcribed interviews, and other pertinent information were organized in mundane files.

Interpretational Analysis

Gall, Borg and Gall (1996) define interpretational analysis as the "process of examining data closely in order to find constructs, themes, and patterns that can be used to describe and explain the phenomenon being studied" (p. 562). In the open coding phase of the study, I examined the surveys, transcripts, and e-journals to assist in the identification of code words or categories of words. Early on in the process of identification of categories and coding, analytic files were built for organizing pieces of information. Using Creswell's (1998) "constant comparative" approach I attempted to find instances that represented the category until each category was "saturated." As more code words emerged in the students' journal entries, the number of categories was expanded and modified, as adjustments were needed.

A constant comparative approach was used in the analysis of the developments in e-journal entries and discussion board to explore the communicative patterns that emerged. The process involved in looking behind what students say was called conceptual analysis by von Glaserfeld (1995). Interactions among the students and between student and teacher were examined through e-mail, discussion board, field notes, and e-journaling. The roles of the students and the teacher along with the relationships were analyzed in an attempt to understand the impact of the new communication tool.

Trustworthiness

In naturalistic studies, trustworthiness is established by the qualities that give the study credibility (Moschkovish & Brenner, 2000). Since research done within the naturalistic paradigm may raise questions regarding the rigor and objectivity of data collected, the construct of trustworthiness addresses the need for a different strategy for examining naturalistic studies. Many researchers maintain trustworthiness is a more appropriate word to use than validity in the context of constructivist or critical research (Kincheloe & McLaren, 1994; Guba & Lincoln, 1989, 1994; Lincoln & Guba, 1985).

Moschkovich and Brenner (2000) refer to Lincoln and Guba's (1985) four aspects in the definition of quality of a research project: (1) truth value, (2) applicability, (3) consistency, and (4) neutrality.

Truth value. Truth value is described as internal validity in traditional research. In the trustworthiness approach, truth value is labeled credibility. "Credibility addresses the fit between the constructed realities of the participants and the reconstructions of their constructs" (Adolphson, 2002, p. 54). This study used several techniques or strategies identified by Guba and Lincoln (1989) for verifying credibility:

- *Prolonged engagement* means that the researcher spent a substantial amount of time involved in the study at the research site to eliminate or control the effects of misinformation, distortion, or misrepresentation. Prolonged engagement builds rapport between the participants and the researcher and promotes trust, while enabling the researcher to better understand the context of the culture (Guba and Lincoln, 1989; Moschkovich & Brenner, 2000).
- *Persistent observation* insures that the researcher has sufficient observations by assuring that enough time has been spent when recurrent patterns become apparent and fewer new types of data need to be collected (Guba and Lincoln, 1989; Moschkovich & Brenner, 2000). "This entails taking an analytical view of the data, looking for important patterns, and

then seeking out further information that confirms or contradicts the emerging understanding of the researcher" (Moschkovich & Brenner, 2000, p. 480).

- *Triangulation*, the best known of the strategies for establishing credibility, is used to verify data by means of multiple sources of data (Moschkovich & Brenner, 2000).

Applicability. In the traditional approach, applicability is defined as external validity or generalizability; the naturalistic counterpart is transferability, or relevance to a different or larger context. "Because understanding the context is one of the principles guiding naturalistic research, naturalistic researchers do not always try to establish how well their results will apply to other contexts. Some naturalistic researchers assert that it is not the researcher's task to determine what is relevant from a study to a context of interest" (Moschkovich & Brenner, 2000, p. 482). Two strategies were used in this study to provide assurances of applicability: thick description and purposeful representative and outlier sampling (Moschkovish & Brenner, 2000; Guba & Lincoln, 1989). In this way, the reader can determine the relevance to different contexts or situations.

Consistency. Consistency is the quality in traditional research defined by reliability; in the naturalistic paradigm it is labeled dependability. Dependability provides strategies to minimize researcher bias. An audit trail of documentation was used in this study to assist in determining dependability, included archived e-journals and audio recordings of interviews (Moschkovich & Brenner, 2000).

Neutrality. Neutrality, objectivity in the traditional approach, is described by confirmability in the naturalist approach. While traditional approaches attempt for researchers to distance themselves from the participants, naturalistic researchers immerse themselves in the lives of the participants. In this study, confirmability was established through explicit description of the role of the researcher as well as an audit trail tracing data to its origins (Moschkovich & Brenner, 2000).

As a researcher/participant, I tried to exhibit qualities of trustworthiness throughout the study by establishing open communications with the students, by listening hermeneutically to them, by asking appropriate questions that encouraged the students to think reflectively, and by being an empathetic communicator. During this time I tried to be a keen observer in the quest for emerging patterns that would enlighten the guiding questions posed for this study.

Chapter 4 discusses the results of the study. The results are organized and discussed in terms of the primary data sources and their function. Remarks and statements are included to assist the reader in making sense of the students' remarks and the communication that was taking place.

CHAPTER FOUR

RESULTS AND DISCUSSION

In this chapter I will describe how learning and classroom instruction were impacted by ubiquitous computer usage during the initial year of an implementation project to provide laptops and Internet access to all students. I will describe how communication patterns evolved as electronic technology was integrated in the college algebra class, how roles and relationships among the students and I changed as the technology was integrated, and how participation with electronic communications contributed to the students' sense making of mathematics.

This study was designed to address these issues associated with the implementation of the laptop project at a small, private church-affiliated university located in a suburban city in the Southwest Plains. In Fall 2001, the campus implemented the laptop project involving the installation of mobile technology. All students and faculty were issued IBM ThinkPad notebook computers that were connected by a wireless, campus-wide local area network (LAN). Students and faculty had the same hardware, software, and wireless capabilities throughout the campus.

There were 47 students in two classes who participated in the study. Students were enrolled in the two spring semester classes of college algebra. Classes met three days a week for 50 minutes each day.

The study began the first day of classes in the second semester of the school year. On the first day of classes the study was described in detail to the two classes of college algebra. All students were given a survey to complete and an informed consent form. Surveys and consent forms were collected from students and evaluated to choose students for the in-depth interviews. The purpose of the survey was two-fold. The survey allowed me to have a demographic view of students as well as assist in the selection of students for in-depth interviews. A sample copy of the survey is included in Appendix A.

The study centered on the students' computer use of e-mail and Blackboard web software to communicate about their mathematics learning experiences. The guiding questions of the study were:

1. How do the communication patterns evolve as electronic technology is integrated in the mathematics courses?
2. How do the roles and relationships among students and faculty change as technology is integrated?
3. How does participation with electronic communications contribute to students' sense making of mathematics?

Students sent weekly responses to required e-journal prompts through e-mail and communicated problems and information to the professor through e-mail. E-mail was used because of ease of transmission of information and e-journals and speediness of conveyance. [See Appendix B for sample e-journal prompts.] Blackboard was used to provide documents and information to students such as Course Policies, class notes, a syllabus, and calendars with assignments. Grades were available for individual student viewing on Blackboard.

Students were encouraged but not required to participate in a discussion or question-and-answer session twice weekly through Discussion Board or Chat Room (parts of the Blackboard software). In-depth pre and post-interviews probed students' reactions to the use of Internet communications in the class. Twelve students were identified as key informants at the beginning of the semester and interviewed at the beginning of the study; ten of those twelve were interviewed again at the end of the semester (one student was unable to attend the interview and one student dropped out of school). All Internet entries were analyzed as key data sources.

The various responses to the e-journals and e-mails received from the students as well as participation in discussion board and chat rooms were examined to explore how communication patterns evolved over the course of the semester, how roles and relationships among students and faculty may have changed relative to the technology, and how the technology assisted the professor in assessing students' sense making in mathematics.

E-journal topics were assigned to all students enrolled in the College Algebra classes. Topics-posted on Blackboard-were assigned each week. Students responded to the e-journal topic by writing a half-page reply and e-mailing the response to the professor on or before 6 pm each Friday. To start off building new relationships, the first e-journal assignment encouraged students to talk about themselves and their feelings towards mathematics.

Survey

A survey (see Appendix A for a copy of the survey) was given to the students on the first day of class to identify student computer experience and background in mathematics. All students completed surveys asking basic questions about their mathematics background, computer usage, expectations for the class, beliefs about the role of the teacher, and mathematics study habits. The main purpose of the survey was to assist the researcher in choosing students for the in-depth interviews. Secondly, survey information regarding computer experience was useful in determining the amount and type of instruction students needed for computer communications with other students and with the professor. Finally, I hoped to gain insights into students' attitudes, perceptions of, and expectations for the class.

The survey consisted of 18 statements for selected responses or open-ended responses by students (See form in Appendix A). Some of the responses to the survey are compiled in Table 1.

Table 1 *Survey Results*

Statement	Response	Morning	Afternoon
What is your classification?	Freshman	13	14
	Sophomore	10	6
	Junior	0	3
	Senior	0	1
What was your last mathematics class?	Intermed Alg	9	4
	H.S. Alg II	3	4
	H.S. PreCal	1	3
	H.S. Calculus	1	4
	Other	6	8
What was your score on the mathematics portion of the ACT?	Below 20	4	4
	21-24	7	5
	25-28	4	10
	29-32	2	2
	33+	0	0
	No response	5	0
At what age did you receive your first computer?	Before 16	12	14
	17-19	8	6
	20+	2	2

Describe how you see yourself as a computer user.	Hacker	0	0
	Expert	6	3
	Do what I need to do	16	18
	Uncomfortable	0	1
Typically, when you do math homework, do you . . .	Work alone	19	17
	Work in sm grp	3	7
	Other	0	2
	(alone, then in a sm grp; always need one-on-one)		
Note: Some students checked more than one response.			
How do you perceive your level of participation in math class?	Uninvolved	1	0
	Silent observer	4	2
	Ask questions when I have them	15	17
	Ask questions to extend my understanding	6	4
	Discuss mathematical ideas	1	0

The survey asked students to describe their experience with various kinds of software as well. Results found that all students had experience in Microsoft Word; many students had at least minimal experience with Microsoft Excel, and most had experience with PowerPoint. Freshmen and transfer students (who have less than 32 credit hours) were given experience with Blackboard software in the fall semester in an orientation class designed to familiarize them with tools needed for college life. All other students had received training on Blackboard during an orientation seminar when issued their computers. A few students had used Blackboard in their Bible classes, one had used Blackboard in a Biology class, but none had used Blackboard in a mathematics class. Other students had at least a working knowledge of Blackboard use.

Respondents listed a variety of ways they planned on using the mathematics learned in this class. Thirteen percent stated they would use the class to fulfill the requirements in their major for graduation; twenty-two percent believed it would help them in future mathematics classes; twenty percent planned on the mathematics helping them in daily life. Other less frequent responses included: "I don't plan on using it"; "This is my last math requirement"; "Use it to help others when I become a teacher"; "I don't"; and "Math is needed in everything that you do." A variety of other answers were given. [See Appendix C for a comprehensive listing of responses.]

Regarding the role of the mathematics teacher in helping students learn mathematics, most students voiced a traditional viewpoint that the role of the teacher is one of direct instruction: "answering questions and explaining math concepts and formulas clearly"; " to effectively transfer the knowledge and capability to perform algebraic equations"; "to teach thoroughly the ideas that are to be on test, as well as cover info not on test"; "go through the steps to solve the problems"; "clearly showing me step by step how the problem [is] solved"; and "teaching it to you." A few students stated the desire for teachers who are "eager on the subject; willing for out of class help"; "to help students fully understand and make things clear"; and "teaching me not just the principle lesson but the entire concept so that I can have a better understanding." Out of the total of forty-four comments, fifteen mentioned "understanding." Five mentioned their need for the teacher to be available outside of class.

In response to a question about the use of the Internet, most of the students surveyed stated that they had never used the Internet to find help with their mathematics. Of those who replied yes to the question, most had used the computer in Intermediate Algebra (a class that precedes College Algebra for students with ACT math scores below 23). The university uses a software package called Assessment and LEarning in Knowledge Spaces (ALEKS) that is a computer-based software package for Intermediate Algebra.

Surveys were a useful tool in identifying computer background and mathematical attitudes and practices. Twelve students were chosen for the in-depth interviews based on their responses to survey items. There were six students chosen from each class, three males and three females. Students were selected for their range of previous mathematical and computer experiences, including some who had taken the developmental mathematics class prior to this class; Students' articulation of negative expectation of computer use, fear of passing the class, and lack of confidence in their own mathematics ability were responses that were the basis for students to be selected for the in-depth interview process. Survey responses also made me cognizant of student familiarity with computers. No major need for computer assistance for the study was found.

E-Journal

E-journal topics were assigned to all students enrolled in the College Algebra classes. Topics, posted on Blackboard, were assigned each week. Students responded to the e-journal topic by writing the minimum of a half-page reply and e-mailing the response to the professor on or before 6 pm each Friday. To start off the building of new relationships, an e-journal topic encouraging students to talk about themselves and their feelings towards mathematics was the introductory topic.

Journal Topic 1.

Please talk to me about yourself and your mathematics. Let me know who you are, especially your feelings about mathematics.

If mathematics were a fruit, it would be a...because...

The first journal topic included two portions, an autobiographical topic and a fruit metaphor. Some students responded to both sections, while others only responded to one of the two. I hoped that by asking students to write an autobiographical response they would talk about what they know the best: themselves, what they care about, and what they feel about mathematics. I wanted to encourage students to focus on their own learning styles and discuss what works and does not work for them in a mathematics world. It gave me an opportunity to know more about the students early in the year. The student responses helped me to see students more as individuals with needs, enthusiasm, fears, and beliefs. The student responses set the tone for a semester-long private conversation about their interests, performance, learning styles, reactions, questions, and concerns without any threat or fear of prejudice (Countryman, 1992; Gordon & Macinnis, 1993).

Only 16 out of 23 students in the morning class submitted an e-journal response to the first assignment despite the fact that the assignment was required of all students. In the afternoon class 19 out of 24 students responded. From the responses from both classes, 20 students responded with negative phrasing about their experiences in mathematics or about themselves. Anna, for example, believed that she was

> born without the folds in my brain that do the math. No matter how hard I have tried or how much tutoring I have gotten, I just cannot grasp it . . . There are many majors that I would love to do but have put aside because I just cannot handle the math part.

Some students mentioned that they did not see a point in taking mathematics. Barb was not too keen on math of any sort, but didn't need to know any extensive math for the field she was going to pursue (Biology). Carl believed he is a little "rusty" in his skills. He further stated that "I don't do really well in math AT ALL . . . I struggle with it but I somehow manage." Some students believed mathematics was "too complicated" with too many rules and too many exceptions. David stated that it "makes my head hurt just thinking about it."

From twenty students who responded to this segment of the journal topic, only 8 students had positive, or at least non-negative responses. Ellen believed that mathematics is a "pretty easy subject . . . I can work very quickly through math problems." Fran had always enjoyed math. Gina enjoyed mathematics somewhat but respected it highly. Previous mathematical classes taken or success in those classes played little difference between those who made positive remarks and those who made negative remarks.

A variety of fruits and vegetables were compared in the second segment of the first week's journal topic. Orange was the most popular fruit to use (5 comparisons). An orange takes a long time to peel by hand, but is easier to get inside with the correct tools; "you have to peel it to get to the juicy part and it's divided into sections just like math is. And sometimes if you have a paper cut the orange juice stings when it gets on the paper cut, just like when you don't understand something in math it stings." A pomegranate (3) has many seeds on the inside, but looks whole on the outside; "looks fairly interesting on the outside but sure does make you pucker when you take a bite;" "you would think tempting juices that drip from it would satisfy your thirst but one sip and don't expect to ever taste sweetness again." A banana (3) "at first doesn't taste so bad but by the end you feel like you are going to be sick. I say this because sometimes at the end of some past math classes I was much more confused than when I began." A coconut (2) is "very tough on the outside and has no regular consistency on the inside . . . Math is tough and seemingly impossible to find any pattern to." "If you can just figure out how to open it, or understand it, it's all sweet milk inside." Others include a tomato (leaves a nasty taste in my mouth, but since it is in the 5 food groups, it is essential to stay alive), grapes (if you plant it, it multiplies), a persimmon, blueberries (end up with a bitter taste in your mouth and stomach as well as stained hands), and kiwi (hairy outer layer brings thoughts of distaste and disgust, much like the thought of math).

The beginning of the semester revealed many of the student's negative and apprehensive feelings toward mathematics. Of the 32 responses describing various fruits and vegetables, 22 were negative and 10 were neutral or positive toward mathematics. Many of the negative descriptions of fruit referred to students' difficulty and struggles with mathematics that were reflected in their responses to the first part of the prompt. Haskell described math as an avocado because it is "useful in the right places but not for everyone. You have to learn to love it." Karla compared mathematics to a grapefruit "because it is really hard to peel (get into and understand) and once you have, it really doesn't taste very good anyway . . . But it does have a lot of important vitamins and sometimes people mix it with other juices to make it stomachable." Linda described mathematics as a pineapple because "it is tough to get into, but once you get the hang of it, it is wonderful and I start to understand." Students seemed to have little difficulty in using the metaphor of the fruit for descriptions about their feelings and the abstract ideas and concepts of mathematics that had eluded them.

Evolving Mathematical Understandings

After using the first week's responses to get to know the students and their attitudes and feelings about mathematics, e-journal queries each week had two questions. The first question asked for students to reflect upon a mathematical concept being studied in class; the second question prompted students to discuss their perceived needs or problems with the speed of the class, the homework, test, or other class activity. Class discussions revealed the students perceived the first question to be the harder prompt to answer; students had to think and reflect on their conceptual understanding. The second question allowed them to open up and express their needs as they took control of their learning. Each week I responded to their essays. My responses varied and typically included follow-up questions, requests for clarification, or positive comments about what had been written.

Students began the semester with great enthusiasm for the prompts and the opportunity to share their thoughts, but as the semester wore on, the number of e-journal submissions decreased. While student responses were required, they were not graded and no grade appeared in the grade book on Blackboard until the end of the semester. A grade was assigned based on the proportion of the number of acceptable journal responses submitted. If a student submitted a response that did not answer either of the two prompts or was extremely short, I asked them to elaborate more and would send the response back for their revision. The sixth week of the semester showed a major decrease in the number of submissions. This week came during a particularly busy time of the semester for students. Each year at this time, many students participate in a school-wide performance, necessitating students to practice several nights a week and culminating in performances for four evenings. The week after spring break also showed a decrease in the number of e-journal submissions. No other pattern appeared in the number of submissions. [See Appendix D for a summary of journal submissions by week and by question.]

The first prompt each week asked students to explain their understanding of a mathematical concept being studied in the class that week. The response allowed me to observe and reflect upon the understandings and sense making of students but also provided information about what they observed, speculated, doubted or confirmed, questioned, posed, or solved. I read the responses each week and tried to understand the sense making of the students. Sometimes students were totally confused and would state very simply that they did not understand. Other times the lack of understanding was shown in the depth of the responses. In a week in which we studied linear correlation and correlation coefficients, students were asked, "What does the correlation coefficient tell us?" While some responses showed an understanding that needed more experience with activities, others clearly showed that they were making a lot of sense of the concept. I have separated these by my interpretation of their understanding. Some responses indicating a lack of understanding included:

- "I don't really understand."
- "I believe that in order for this process to work successfully the correlation coefficient would be very high."
- "The correlation coefficient is the estimated line that we get for the variable "r". It gives us an approximate average of how close we are to the actual right answer."
- "According to the book, the correlation coefficient is used to describe the strength of the linear relationship between x and y."

Student responses that exhibited partial understanding included:

- "The correlation coefficient tells us how close together the points are on a scatter plot."
- "The Correlation Coefficient tells us the strength of the linear relationship between x and y. The closer the variable is to one, the stronger the relationship will be. This is one of those concepts that will take me a little work to really grab ahold [sic] of; partly because of my own unwillingness I'm sure."

Responses of students whose understanding appears to be consistent with the discourse domain of mathematics included:

- "A correlation coefficient is the number that shows the relationship between x and y in a linear equation. It describes how close or the strength of the correlation, relationship between x and y. If r falls between 1 and –1, the closer to one the closer the fit. In a way, it adds credibility to your linear equation, it is not a cause and effect, but it does indicate you are on the right track or should use your line to make an educated prediction."

- "The Correlation Coefficient is a term used in linear regression to show how closely a straight line would pass to all the points on a scatter plot. The number must always be between 1 and –1. I think of it as a percentage of accuracy. For example, if you have a correlation coefficient of .9899 and another of .7546, then the .9899 coefficient is much closer to be a more accurate representation of all the points. If the coefficient is a positive integer, then it is a line that is sloped up. If it is a negative integer, then it is a line that is sloped down."

As the students attempted to fulfill requirements of the e-journal and to articulate their thoughts, they reflected on connections between the algebra activities from class, their past experiences with algebra, and definitions from their textbook.

Students formulated ideas in their writings that they might have been unwilling to verbalize in class. During the time the class was studying zeroes of quadratic functions, for example, the e-journal questions asked,

> What are zeros? Describe them algebraically and graphically. What is their importance?
> How can you tell the difference between a linear function and a quadratic function: What is the difference between the zeros for a linear function and those of a quadratic function?

Natalie, in her response, quoted a definition from the text, but then stated,

> My definition is a zero is the same as the x value. Algebraically it is when you find the value of x. Graphically it is the point where the line hits the x-axis. I really don't know why they are important. I guess to tell us what is the x value.
>
> A linear function is when there is a straight line on a graph. A quadratic function has parabola on the graph. And to be perfectly honest I don't know the difference in the zeros for a linear or quadratic function.

Writing an e-journal response to the question about the meaning of zeroes of quadratic functions provided Natalie with the opportunity to formulate a definition that she was able to articulate in her response, but may not have verbalized in a class full of her peers. By extending and personalizing the definition, Natalie not only used the e-journal to clarify her own thinking but to reflect upon her understanding of the book. The depth of the definition and Natalie's use of the words, "I guess", shows that her idea of the importance of zeroes was still under construction. The last part of her response indicated that she had not made the connections between the zeros of linear and quadratic functions. Other responses typical of those who seemed to understand showed the richness of mathematical reflecting that was occurring included:

- "You can tell a difference between a linear function and a quadratic function by looking at the x value. If there is an x^2 value, then the function will be quadratic; if there is only an x, then the function is linear. You also can tell the difference between a linear function and a quadratic function by graphing it. A quadratic function comes out as a hyperbola; a linear function comes out as a line. Fairly simple. The difference between the zeros of a linear function and a quadratic function are that the zeros of a quadratic function can be on the x-axis, there could be two, or there could be none; zeros for a linear function are always the x-intercept."

- "An input c of a function f is called a zero of the function, if the output for c is 0. That is, f(c)= 0. Basically what are you 'x' values when you plug in a zero for the y variable. It tells us where the graph crosses the x axis, that is important to know when drawing the graph."

- "Zeros are what x equals when y is 0. You set the equation for f(x) equals 0. Then you solve for x. It's really easy!! Graphically the zeros are where the line crosses the x-axis when y equals zero. You push 2nd Calc and go to Zero, set the left and right boundaries and then you'll have your answer!" [These are instructions for finding the zeros graphically on her graphing calculator.]
  A quadratic function is a number squared and it will be given in the equation: ax^2+bx+c. The x^2 indicates a parabola which is part of a quadratic. This means that the parabola will cross the x-axis in two places meaning it cannot just be a straight line. In a linear equation there is only one value for x this meaning that the line only crosses the x-axis in one place. In a quadratic function there will be two solutions for x. In a linear there is only one solution for x."

When students gave unclear, short, and awkward responses or expressed uncertainty when answering the question about conceptual understanding, I interpreted it to mean that the students were having difficulties making sense of that particular concept. Each time that this occurred, I responded to the student with a question to assist the student in building a fuller understanding of the concept by encouraging more conversation and more discussion of the mathematical ideas. Student discussions of mathematical ideas provided a basis for further conversations to assist in sense making and understanding. When asked to explain what the zeroes of a quadratic function are algebraically and graphically, Ira said, "Zeros are the root. Algebraically, they are the center point in the number line. Graphically, they are the origins of all graphs." When asked the importance of zeros, Ira replied, "They are the point between negative and positive. It's the only number there when nothing is left." Ira's responses started an e-mail conversation between the two of us that first had me asking him to "Please clarify your definition so that I could better understand what you are describing. Tell me more." I quickly discovered that Ira was confusing the number zero with the concept of zeros of a function. Ira had used his textbook and a dictionary in an attempt to connect the meanings that he found in both the dictionary and the textbook. Ira's responses to the e-journal provided an opportunity for me to continue the conversation to further discuss and make connections between Ira's understanding of roots and the zeros of a function. I also included activities for our class time that further explored the concept of zeros of a function.

Evolving Mathematical Communications

The semester began with 70% of the morning class and 83% of the afternoon class submitting journal responses. Over the semester, the morning class averaged a 43% response rate and the afternoon class averaged a 58% responses rate for the e-journals. Despite many of the students failing to submit e-journals, responses provided student communication with me that would generally have been nonexistent. Some students expressed the frustration they were having with mathematics as well as life in general. Sometimes my role became one of listener to their problems and disappointments with life. Molly described her frustration by saying "I am doing 100 things and not doing very well at any of them. Between trying to plan a wedding, spring sing, school, work, trying to sleep, have time with God, teaching Bible classes, I sometimes feel lost in it all." Olivia described feelings of frustration after a test. "I have been having trouble with a girl and it is starting to disrupt my life. . . .[A]ll I could think about [during a test] was lying in my bed and crying or giving it up and going home." Towards the middle of the semester, Barb added this statement to her e-journal assignment:

> Now considering that there really is no way that I am going to be able to fill up half a page with the above question, I figured that I would tell you a little bit about how my life is going. Lately, I have had no incentive to do work, go to class, go to work, etc. I would prefer to sleep all day long, and when the occasion hits me, eat. I have to give myself a pep talk in the morning before I roll out of bed, saying that I HAVE to get up, I NEED to be nice to others, I NEED to do my homework, etc. It is terrible considering that I know that I need to be doing stuff for school, but the only thing that I can think of is how much I want to go home for spring break. After spring break, I honestly don't know how I am going to keep myself going, I guess I will have to look forward to summer. I am not sure. Now that I have that off my chest, I apologize for skipping class. I know that you put hard work into what you do, and it wasn't very nice of me to skip. I suppose that is all that I have to say for now.

In addition to providing opportunities for students to think through relationships and concepts discussed in class, e-journals gave students opportunities to talk to someone about the frustrations and difficulties in their lives.

Participation in e-journals was the only communication means that many students utilized with the professor. Without the e-journals to open the lines of communication, several painfully shy students may never have "talked" to the professor, in or out of class. In the surveys taken at the beginning of the semester, 13% of the students described themselves as silent observers in the mathematics classroom. None of the "silent observers," made use of one-on-one tutoring or assistance or conversation with me outside of class time. However, two of the "silent observers" felt that the relationship between us was comfortable enough to tell me about personal problems. One of the "silent observers" e-mailed me six times during the semester with questions about class; another sent me five e-mails with questions; two "silent observers" dropped the class; one student that I would classify as a "silent observer," though she did not describe herself as a "silent observer," sent me eight e-mails talking about her personal life or asking questions.

While the e-journals supported the communication between the student and the professor, it also seemed to encourage independence of the student by encouraging the student to take ownership of the learning through their expression of ideas, concepts, and methods as they expressed these in their own words. Weekly prompts asked students to describe and connect ideas and concepts encountered in the classroom with their understanding of the concepts and connections to the world outside of the classroom. During a time in which the class was studying about increasing, decreasing, and constant functions, students were asked: "Describe a real-world situation that could be modeled by a function that is, in turn, increasing, then constant, and finally decreasing." Student responses included:

- "Well I think that the real life situation would be our economy. We were doing increasingly better up until Sep. 11, 2001, after that we topped out and stayed steady for a few weeks, then we ended up going into a recession due to cut backs and oversensitization of the attack and fears that stock holders have about the market crashing."

- "I think a real world situation . . . would be an airplane flight. It is increasing as it takes off the runway at the airport, then when you get to a certain altitude they level off and it remains constant, and then when you are getting ready to land the plane starts to decrease."

- "A real world situation could be cooking. You put something into the oven, from that point, the heat starts to increase until it gets to the temperature you set it at. And then it is constant for whatever amount of time it needs to cook. After that amount of time, the food is then taken out of the oven. The temperature decreases from that point on."

Students were encouraged to write openly about problems they were having in the classroom, their needs because of different learning styles, and the successes they felt. The openness and encouragement fostered through the communications allowed students to take more responsibility for what was going on in class, and to understand their roles as contributors to the classroom conversations. Participating in the conversation became an ethic of the class, communicating to students that their on-going contributions were central to the process of learning (Countryman, 1992). "When we ask students to talk or write about their thinking, we are telling them that we value what they have to say. . . . By presenting what they think is important, students exercise greater power and control over their learning, that is, they become empowered" (Mumme & Shepherd, 1990, p. 19). Examples of students e-journal prompts showing students presenting what they think is important:

- "…Of course, these [reasons for doing poorly on a test] are all just excuses that I am making, because in all honesty, I'm just getting lazy. I'm finding it harder and harder to have motivation to do really well. I chose to not bring my laptop class today, because I thought it would help me concentrate, and sure enough it did."

- "I have always struggled with algebra, so I just need to spend an extra amount of time studying. I might try to go through some of the evens on the homework that I have not worked. I think the hardest thing for me is that I am not sure how to study for math."

- "Let me just start out by saying I think class is going good, the pace and everything is great! I have just one thing I would like to say. I have noticed this happening several times in class and not just with my questions. . . . You told us to do our homework before class so we can ask questions about it. When we do, in these cases you don't answer the questions over the problem we don't know how to do and you do the problems we have already figured out. If you just take the three minutes to answer the one question we have then we will go ahead and be able to finish the rest of the homework problems in that section. Then that doesn't punish the people that are keeping up with pace and homework. In many cases all a few of us need is just a quick example and then we can figure it out. I want to thank you for asking for our inputs about class. I think that shows how much you care and want to help."

E-journals assisted in the creation of open relationships through communication; e-mails opened the lines of communication further

Unsolicited E-mails: Unanticipated Results

During the first few weeks of the semester, students began to use their computer to take advantage of the opportunities for communication using e-mail. With a wireless computing network available everywhere on campus, e-mail can be used anywhere and anytime. During the study, I spent most of the days while not in class in my office working or meeting with students. While in the office, a tone makes me aware of e-mail instantaneously. Because of the study, I attempted to respond to e-mails in less than a minute. While at home, I made sure that I checked e-mail on an hourly basis. On the two evenings in which discussion board time was scheduled, I checked e-mail continually. I felt that the immediacy of the response would encourage students to use the computer communications more readily.

At the beginning of the semester, one struggling student sent 6 e-mails in her first week of class. Barb made an interesting comment in response to the question in the e-journal posting asking her to describe kinds of things that make it easier for her to learn mathematics. "Something else that is helpful to me is to have someone close that I can ask questions. When I have a problem in math, it is very helpful to me to get the question answered as soon as possible. I have problems moving on and leaving something unfinished." E-mails allowed for that close, fast answer for students like Barb.

E-mail and e-journals are so closely tied together that it is difficult to separate their impact upon the students and the teacher. During the first week of classes, e-mails and e-journals allowed the professor to discover and address a problem a student had vocalized. In describing her feelings about mathematics in her first response, Natalie said, "I am already lost." When the student admitted that she was lost already, e-mail allowed the teacher to quickly reach out to the student to identify what was causing the desperate feelings and assist the student in handling the problems she was facing.

As the semester progressed, students began writing their e-journal postings, then attaching a note or a question at the end of the submission. A spirit of conversation was begun that helped to encourage an openness between students and professor. To encourage the "conversation," to build positive feelings in each student, and to identify any changing roles and relationships, I tried to make comments about each e-journal submission, either making a positive remark about what the student had stated or described, or asking the student a question to assist in clarification of the meaning. Research by Gordon and Macinnis (1993) recommend responses to journal prompts be regular and sincere, but not judgmental or evaluative. They found that teacher responses of comments, questions, notes of encouragement or assurance show that the teacher is listening and cares. Thompson (as cited in Gordon and Macinnis, 1993) states that the intent of the response is to "assure, teach, reteach, suggest, nudge and question" (p. 42).

Over the 15 weeks of the semester, including the week of finals, there were 244 total e-mails sent by students in the two classes. While enrollment remained virtually the same in the different classes, the morning class sent 147 e-mails while the afternoon group sent 97 e-mails. The morning class averaged around 10 e-mails each week from 6 different students. The afternoon class averaged around 6 e-mails each week from 4 different students. [See Appendix D for Compiled Data for all data sources.]

Discussion Board/Virtual Chat

Blackboard software included two tools that can be useful for discussion among classes or student groups called Discussion Board and Virtual Chat. While students were not required to use the discussion board or chat room feature for the College Algebra class, both tools were activated. Students were informed as to their use and availability and encouraged to participate in the activities surrounding Discussion Board and Virtual Chat in the evenings or any other time.

Initial Discussion Board format

I began the semester using Discussion Board to elicit responses to one of two simultaneous threads. A thread was posted with a question designed to provoke student thinking. The first thread was "What do you think it means to do mathematics?" In addition, an open thread was posted for students to use to post questions or ideas on the Discussion Board. Twice a week on Tuesday and Thursday evenings, I was available online for office hours on the Discussion Board. During the first week of the study, no one responded to the thought-provoking question or to the open forum for homework questions. By the second week of class, one student came on line to ask a question about what homework was due. The third week had no one responding to the meaning of mathematics but did have 5 (4 from the morning class) students come on line with questions about assignments. After the third week, students from the early class failed to come online; only two students asked questions the rest of the semester. Students in the afternoon class stayed with the discussion board a little longer, averaging 2 people each week for 5 weeks. [See Appendix D for comprehensive listing of the number of responses on the Discussion Board.] By the fourth week of the semester, I learned through e-mails and e-journals that some students would open the Discussion Board with a question or response then leave before someone had a chance to respond

Adaptations in the Discussion Board format

At this point in time, I decided to see if changes in the Discussion Board format could lure the students into making use of it. During the sixth week of the semester, the prompt asked how Discussion Board could be adapted so that it better served the students and their needs. Students appeared to be apathetic. Landon replied, "I have never used discussion board and probably wont [sic] unless I'm really stumped on something and that hasn't happened yet." Fran said that she doesn't think she would use the Discussion Board anyway. "By the time I get to my room after track, activities, and other homework it is extremely late. You wouldn't want to be on Discussion Board when I am doing my work." Other students voiced similar opinions about the difficulty in scheduling a time in which we could meet online.

Many of the students stated that they didn't feel the need for a place for discussion of problems or that the times were inconvenient. In response to student submissions to the journal query, two changes were made. The format was changed to add Virtual Chat and the days that the Discussion Board and Virtual Chat were "live" were changed in an attempt to fit the schedules of students in the class. Instead of having a Tuesday and a Thursday evening forum, times were changed to Monday and Thursday evenings from 9-10:30 pm.

Another issue with not using Discussion Board and Virtual Chat features of Blackboard involved problems with conveying mathematics problems electronically. Concepts studied in class sometimes involved radical equations or equations with exponents. E-journal responses and an open discussion in class revealed that students found radicals and exponents were both difficult to type on the computer, which frustrated them and discouraged them from joining in discussions or posing questions. The Virtual Chat venue includes a whiteboard in which students are able to draw and write mathematical symbols a little easier using a mouse. I obtained a tablet and pen for use on the whiteboard to make it easier for me to write symbols and draw. After discussing the changes in class, I attempted to attract more students to the website with opportunities for extra credit points. Students who added a thread to Discussion Board that exhibited a thoughtful response or students who contributed to a student's understanding were rewarded with extra credit points on their grade. I believed that if I could get the students to join in on a discussion or to participate in the Virtual Classroom, then they might find another avenue for taking control of their learning.

Virtual Chat may be a much better alternative to Discussion Board because students who use an external mouse are able to draw and write their equations by hand on the whiteboard. Since it was the ninth week of the semester when we attempted the change to Virtual Classroom, it is difficult to say whether the students would have been more receptive to its use if we had started the semester with it. Since there was little participation, it was difficult to use as a tool for understanding the sense making of the students.

Interviews

Twelve students were chosen early in the study from the surveys given on the first day of class for in-depth interviews. There was an introductory initial interview [see Appendix F for sample initial interview questions] in which I individually talked to the twelve students about their access to computers, their background with computers and mathematics, and their attitudes and expectations of the course and me. During the last week of the semester, I interviewed the same students to question them about their experiences of the semester [see Appendix E for sample final interview questions]. Of the twelve students who were interviewed at the beginning of the semester, only ten could be interviewed at the conclusion of the semester. One student was no longer enrolled in school because of medical problems and one student was unable to be interviewed.

One of the questions asked the students to describe their feelings about the laptop computer program. All ten of the students spoke positively about the laptop program, ranging from some who were very enthusiastic to a few who had mildly positive remarks. Jennifer enthusiastically said, "I love it! I love it, yeah." When asked why she felt that way, she explained:

> It makes everything so much easier. I can, like, type faster than I write, so taking notes in class is much easier on the computer. If I'm in one class and nothing's going on, maybe there's a little pause between something, and maybe I have another project I can just open up Explorer and do a little bit of research while I'm sitting right there. It's easier to keep in touch with my family and, you know, my friends . . . I have other friends that are transferring to other schools, you know, or that went to different schools. I just keep thinking, 'How did they live without their laptop?!' . . . I just don't know what I would do if I went to a college that didn't have them. I really, really enjoy it. . . . I just like being able to communicate with anyone no matter where I am.

Jennifer communicated on a regular basis with all 22 of her mom's family. "It's actually gotten me to communicate more with them and it's brought us all closer together. So, I like the communication." While Jennifer was the most enthusiastic student who described her joy of communicating, other students mentioned communication with friends and family as a reason for appreciating having the wireless laptop program. Ira said that the easy access was what he liked the most about the program. "I don't have to go to the library and look up some of the information that I need. It saves me a lot of time." Peter liked

> the portability of all my files . . . I like it that I grab my little black box, my little laptop, and I can go off to class and I have everything I've ever done this year . . . All my research that I've done for different subjects . . . It's all right there. And I really, really like that. And I don't have to have notebooks to fumble through, because I'm probably not the most organized person as far as paper work goes. I know where all my stuff is, but with this laptop everything's just right there.

While Rachel likes having a computer and being able to take it to class to take notes, she believed that personal ownership was her main reason for enjoying her computer. "You always have to share a room and you have to share a bathroom. You have to share all sorts of stuff, but you have your own computer, and that's kind of nice to just have something that is mine. I can do whatever I want on there." Tamara likes being able to "turn in stuff online and to check schedules. The fact that you have all your assignments posted online...that helps out so much because, you know, you'll, like, have nothing to do" so you don't "have to worry about if you wrote it [your assignment] down wrong or anything like that." Access and portability were Yvonne's main reasons for liking the laptop program. She added,

> I like that all of us are connected together, like, giving assignments over the web, then e-mail, I mean its keep all of our classes connected . . . If we didn't have our laptops, it would be very difficult to do that. Because not every student would have access . . . I can take it anywhere I go. I like being able to just pick it up and leave and have it in every class. It's just very easy.

As students explored and embraced their laptop computers, the communication patterns evolved into a much broader spectrum. All students who were interviewed talked about the two-edged sword embedded in computer use. The laptop became a replacement for the phone and answering machine. Will said, " I don't have to go out and find a phone to check messages and stuff. I can e-mail. I can communicate and get information. I can do research while I'm at work; (I work on campus)." Scott, also, enjoys the "connection" he gets from the laptop. "You can talk to your friends here, and then you can still keep in touch with your friends at home . . . I e-mail my grandma a lot . . . It's a lot easier to e-mail."

While students were very pleased with their new communicator, they voiced the problems that went along with the new technology. Peter noted that the thing he likes the least about his computer is "the temptation to not pay attention in class, to Instant Message, to, you know, surf the web, check out" interesting information. Rachel found the computer to always be a distraction. When asked if she was getting better at ignoring the distraction, she stated, "I think I'm worse." Tamara did not agree that the computer is the problem. "I just feel like it's a maturity level thing. If you're able to handle it, then you do. And if you aren't, then you learn eventually."

Student communication with the professor was established through e-journals and e-mails. Discussion Board and Virtual Classroom were not utilized as much by the students. During the interview, Jennifer revealed that she often went to the website, but rarely would ask a question, make a remark, or add to the discussion.

> I always just go in there, and I'll just look and there are not questions, I'll sit … or if I see someone else in there, I'll wait until they ask something … You know, I'd rather someone else just ask the question and then, like, I … 'Okay. I kind of get it.'… I guess it kind of intimidates me, because the way they answer it is much more clear than … you know, we get the same answer but they can put it into words better than I can.

When I told her that someone else might understand her words better than the other person's words and that she could rephrase what the other person said, Jennifer responded, I sit there and think, 'How would I put that into words?' And then I read theirs and I was like, 'Wow.' So I feel as dumb as a rock." Ira had never used either Discussion Board or Virtual Chat and couldn't say that it was helpful. He did feel that if the class got more involved using either Discussion Board or Virtual Chat could really be a positive influence on learning. "(I)f you take advantage of it [Discussion Board], I mean, it definitely would probably be helpful. But I just tend to be more … I want to, like, talk to them [the other students]." Molly "never really understood it." Problems typing math on a computer caused Rachel to avoid Discussion Board. "I don't feel like I could get my question across, typing it." Scott made a suggestion. "I think the Virtual Classroom is harder to follow than Discussion Board because you have, like six people talking at once. [He had used both during a biology class.] I think Discussion Board would be easier one-on-one, because you could ask a question, you could answer it … Instant Messenger would be better than Virtual Classroom." When asked why Instant Messenger would be better, his quick response was, "Just because." He again voiced feelings of shyness. "I feel stupid asking questions that a lot of people would know …I've always never had the nerve to ask. I just follow along and then ask later."

When asked how the computer technology affected their learning, there were mixed feelings. While Peter couldn't decide whether the computer technology benefited or hurt him, he did decide that it was the best thing for teacher-student communication. "As far as communication goes, there's nothing better between a teacher and a student. So, whenever I've benefited in your class, from using a laptop, it would be because of the ease of communication." Ira didn't think the computers had affected his learning at all, but did state, "it's mostly useful for journal assignments." While Tamara didn't feel that the she had personally been affected by the computer technology, she stated, "I think, for a lot of people, who do have a lot of questions, I think they find it very helpful, because there are a lot of shy people in our class. And I think they find the online thing really helpful, just because they don't feel comfortable, like actually going to you for help … and so they feel … but at the same time, it's kind of an excuse, a way to get around it, also." On the negative side, Yvonne remarked, "I don't know. I haven't brought my computer to your class lately because I think that I'm paying attention [when I have my computer with me], and I'll look up and notice that I have no idea what just happened in the last 30 seconds." E-mails and e-journals provided insights on student sense making and communication patterns and roles; interviews were used to triangulate those findings from e-journals and e-mails.

Summary of Results

When I started the study, there were three guiding questions I wanted to answer:

1. How do the communication patterns evolve as electronic technology is integrated in the mathematics courses?
2. How do the roles and relationships among students and faculty change as technology is integrated?
3. How does participation with electronic communications contribute to students' sense making of mathematics?

As the electronic technology was integrated in the college algebra classes, communications among the students and I evolved into a pattern that was different than I had ever encountered with previous classes. Many students felt comfortable enough to disclose personal and mathematical frustrations to me through the e-journals and the e-mails. Changes in the patterns of communication between students and professor, students and parents, and students and friends became obvious in discussions with students. The change in the communication patterns sometimes benefited the students as they sought assistance with homework from me and from other friends. However, since change can be beneficial or detrimental, sometimes communications got in the way of more important aspects of the students life. Many students mentioned Instant Messenger as a blessing and a curse. Some students like Haskell had to make a special effort to avoid its distracting and addictive nature by totally avoiding it for a week. The use of the wireless network that students had access to on their computers made communication a commodity that could be accessed anywhere on campus and anytime of the day or night.

As the communication patterns evolved, the roles and relationships between the students and me also evolved. Instead of the students seeing me only in the classroom, they were able to contact me, interact with me, and receive help for their problems more than just the three hours a week that the class met. Because of the number of e-mails I received, I believe the students were not as intimidated by my role as teacher and felt that I was more approachable. This was also corroborated in the final interviews with the students.

Participation with electronic communications did not contribute to students' sense making, as I had thought that it would. Most of the students did not participate in Discussion Board or Virtual Chat activities. However, e-journals helped me in determining the conceptual understanding and students' sense making through responses in which they explained their understanding of various concepts each week. When a student was unable to describe ideas or concepts, I was able to immediately chat about those ideas or concepts with the student, hoping to assist the student in the enhancement of the sense making or to make adjustments in class discussions. Sometimes in the past, it was only when a formal assessment occurred that I discover the lack of understanding in a student.

In chapter five I will use the findings from this chapter to draw conclusions that may provide answers to the three guiding questions that began this study: How do the communication patterns evolve as electronic technology is integrated in the mathematics courses? How do the roles and relationships among students and faculty change as technology is integrated? How does participation with electronic communications contribute to students' sense making of mathematics?

CHAPTER FIVE

ANALYSIS AND IMPLICATIONS

> But of all other stupendous inventions, what sublimity of mind must have been his who conceived how to communicate his most secret thoughts to any other person, though very far distant either in time or place? And with no greater difficulty than the various arrangement of two dozen little signs upon paper? Let this be the seal of all the admirable inventions of man (Galileo, as cited in Shlain, 1998, p. 1).

"Emerging information technologies now converging on the Internet are triggering significant changes in the kinds of learners served by universities, how courses and programmes of study are delivered, and even the way in which teaching staffs and organizational structures are configured" (Cookson, 2000, p. 71). Transcending time and space, learning environments shaped by emerging, developing digital technologies may pose opportunities and/or hazards to higher education institutions. It is in this environment of change that I chose to situate my study. As a part of a university launching a ubiquitous, wireless computing program, I was in a unique position during the initial year of the program to research the impact of the wireless network on students in a mathematics classroom.

My study looked at the communication patterns that evolved as electronic technology was integrated in a mathematics course and how inter- and intra-communications may affect learning. I observed the emerging communication patterns as they altered the roles and relationships among the students and faculty, and the developing mathematical understandings of the students. When I started the study, there were three guiding questions I wanted to answer:

4. How do the communication patterns evolve as electronic technology is integrated in the mathematics courses?
5. How do the roles and relationships among students and faculty change as technology is integrated?
6. How does participation with electronic communications contribute to students' sense making of mathematics?

This chapter discusses the findings that emerged from the data presented in the previous chapter and reflects upon the potential implications of those findings.

Findings

As the electronic technology was integrated in the college algebra classes, communication between the students and me evolved into different patterns than I had ever encountered. Many students felt comfortable enough to disclose personal and mathematical frustrations to me through the e-journals and the e-mails. Although these kinds of disclosures had happened occasionally in the past, they had not occurred with the frequency and the regularity as they did this semester. The use of the wireless network that students had access to on their computers made wireless-electronic communication a commodity that could be accessed anywhere on campus and anytime of the day or night. Changes in the patterns of communication due to Internet availability and use between students and professor, students and their own parents, and students and friends became obvious in discussions with students. The change in the communication patterns sometimes supported the students' needs as they sought assistance with homework from me and from other friends. However, sometimes communications got in the way of more important aspects of the students' life. Many students mentioned Instant Messenger (IM) as a blessing and a curse. Some students had to make a special effort to avoid its distracting and addictive nature by totally avoiding it for a week.

As the communication patterns evolved, the roles and relationships between the students and me also evolved. Instead of the students seeing me only in the classroom, they were able to contact me, interact with me, and receive help for their problems more than just the three hours a week that the class met. Because of the number of e-mails I received, I believe the students were not as intimidated by my role as teacher and felt that I was more approachable. While not all students equally took advantage of my virtual availability, more students contacted me by e-mail than typically would take advantage of office hours.

Participation with electronic communications did not contribute to students' sense making in the way I had thought that it would. While most of the students did not participate in Discussion Board or Virtual Chat activities, e-journals helped me determine the conceptual understanding and students' sense making through responses to my prompts to explain their understanding of various concepts each week. When a student was unable to describe ideas or concepts, I was able to immediately converse about those ideas or concepts with the student, hoping to assist the student in the sense-making process. Many times in the past, I had discovered the lack of understanding in a student only when a formal assessment had occurred.

Leikin and Zaslavsky (1997) believe low-achieving students are often reluctant to seek help from their classmates, for fear of embarrassment. When they do seek help, it is mainly from their teacher, who generally does not have enough time to provide the necessary help needed. In this study I found that it was not only the low achieving students who seemed embarrassed seeking help, but the students who seemed successful in mathematics achievement were embarrassed when seeking help or describing their understanding in class. My study explored how e-journals, e-mail, Discussion Board, and Virtual Chat may support students' learning and overcome their reluctance to seek help when needed.

In an effort to better describe the findings from the study, I will examine and discuss the findings in terms of the primary data sources: e-journals and e-mail, discussion board or virtual chat, and interviews. I am grouping e-journals and e-mail together because students submitted e-journals through e-mail or as an attachment to e-mail.

Required e-journals and unsoliticited e-mails

As new semesters began in January, students are eager yet apprehensive at the promise of new beginnings. While I look for signs and signals to try to understand the evolving communication patterns as the semester progresses, students look for signs and signals of what to expect from the course as far as difficulty and what to expect from me as the teacher.

The first e-journal assignment was designed to encourage and open up communications with the students. As I read their first e-journal submissions, I found evidence that many had a dark history of mathematical understanding and feelings. As the semester progressed, for the majority of the students, e-journals and e-mails provided opportunities for them and me to explore those feelings and understandings.

Communication patterns. While e-journal prompts had two questions for the students to answer each week, many students took the opportunity to add conversations to the e-journal about their successes or their dilemmas both in life and in mathematics. E-mail and e-journals provided the opportunities to give individualized feedback and to extend classroom conversation, but it also enabled interactions that could never occur in the classroom because of time, conversation flow, interpersonal dynamics, cultural influences, and language barriers (Kirkley, Savery, & Grabner-Hagen, 1998). This extension of the classroom dialogue provided new opportunities for students to think through issues that the instructor, or a large majority of the class members, might have considered to be less important to the group but that were important to that member of the class. E-mail and e-journals also permitted a more diverse set of conceptual topics to be discussed in depth.

In the pattern of the traditional classroom, the teacher is the focus of the discourse. The teacher, the authority, poses questions to the students. Students make attempts to respond with correct answers to the teacher. The teacher listens for the "correct" response before the lesson continues along its planned course. Listening is generally evaluative, but may be interpretive (see Davis, 1997). In both categories of listening, authority remains with the teacher, who is the center of communications. Notice in Figure 1 that the large circle in the center represents the teacher as the center of the communications, with arrows representing the discourse that occurs between the teacher and the students. Each of the other circles grouped around the teacher represent the students responding to the teacher.

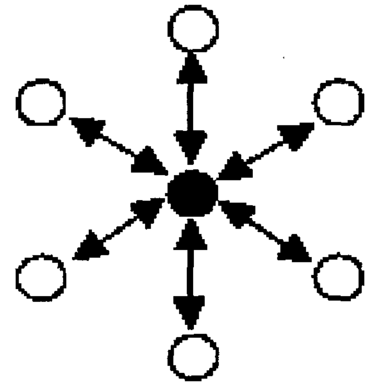

Figure 1.

In this study, the communication patterns were changed through the added dimension in the students' and the teacher's opportunities to reflect. E-journals allowed not only hermeneutical listening described by Davis (1997), but also hermeneutical listening from a potentially more holistic viewpoint. Hermeneutical listening focuses on the dynamic interdependence of student and context, "thought and action, knowledge and knower, self and other, individual and collective, rather than on autonomous constitution or construction" (p. 370). From a holistic viewpoint, hermeneutical listening may have the potential to frame interactive events. Student and teacher experiences with mathematical hermeneutical listening describe the potential for individuals to come together in a shared or joint activity, of communicating about their mathematical ideas and understandings. The holistic viewpoint connects the classroom with the communications from the e-journals because of the students' reflection on their understanding and my reflecting on their e-journals. This provided a richness of experiences directly associated with the reflections from the e-journals. Figure 2 is a representation of the communication patterns that evolved through the course of the study.

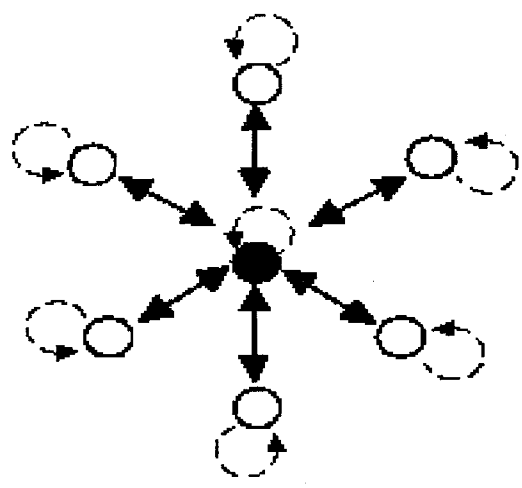

Figure 2

As in Figure 1, the teacher is still the hub, the center and conduit of communications with the students. The arrows connecting the teacher and the students depict the discourse occurring through the e-journals and in classroom dialogue. The difference is that now, the students and the teacher have a new dimension. The process of reflectivity is represented by the circular dotted line that is adjacent to each student and the teacher. (Not all students may reflect, hence the dotted line.) When students and teachers reflect upon their understanding, it affords them opportunities for sense making and enriches their understanding through their reflections.

Student sense-making of mathematics. Doll (1993) argues the role of curriculum is a process that should be rich, recursive, relational, and rigorous. E-journals provided a rich, recursive, relational, and rigorous environment in which meaning and understanding from a hermeneutic frame emerge from the process reflective conversation. Meaning is based on discourse, that is, having a discourse with others. The e-journals provided a conversation and discourse in which questions were asked, issues were posed, "that go beyond the factual into the interpretive" (p.

151). Conversation develops "its richness by focusing heavily (but not exclusively) on the interpretation of metaphors, myths, and narratives" (p. 176). When rich questions are asked that elicit responses that serve the recursive function of keeping the conversation going, "passages are negotiated" (p. 151) between the mathematics and the student, between the professor and the student, and between experience and consciousness. E-journals provided opportunities for recursive reflection for thoughts to "leap back on themselves" (p. 178).

While I was looking for the potential of e-journals for students to reflect upon their learning and sense making in mathematics, perhaps the greatest value of the e-journal were the insights I gained. The e-journals may have promoted student learning through their reflections, but the e-journals definitely provided me with important insights into the complexity of their meaning making process. As the students attempted to describe a concept or idea in their e-journals, I was better able to share the meanings and understandings they had constructed or failed to construct. Because the e-journal was not seen as an evaluative tool, it became a "place to take risks, to make mistakes, to sort out and to be open about problems they had in understanding mathematics" (Gordon & Macinnis, 1993, p. 41).

Examples of student journal entries that show their lack of understanding include:

- "I hate to say it but I have absolutely no idea what an example of the functions would be in the real world. I would like to know."
- "I've been thinking about this journal question for about a day now, and I just don't really know how to answer it. I really cannot think of

any real life inverses. I really tried, I even looked up stuff on the Internet, but all I got were lesson plans that were online."

- "Maybe I'm just not feeling very creative today, but I just can't seem to think of an answer for what it means to do mathematics."

E-journals were used on an individual and a holistic basis. First, I would respond individually to each student's e-journal in some way. Then, depending upon the problems that the students had in understanding and making sense of the mathematical concept discussed that week, classroom dialogue and activities were revised to include more time to sort out the problems and difficulties I found through my reflections on their responses.

The study used e-mails to provide prompt responses to e-journals and questions from students. E-journals and e-mails more seamlessly and perhaps more naturally provided spaces for reflection-in-action, removing the artificiality of a 55 minute class meeting 3 times a week. When students sent questions through e-mail or e-journals, a response to that question was generally forwarded within an hour; emails sent after 11 pm in the evening were responded to before 7:30 am the following morning. Because of the quick responses, students believed they could depend upon me for assistance if they were stumped with a problem. Many students submitted questions early in the morning, between 12 am and 2 am on the day a homework assignment was due.

Through the e-journals and e-mails, I learned that students wanted to be heard as they made remarks about what helped them learn better. They were made aware that their requests were considered and would result in a change of instruction or an explanation of why change was not possible or feasible. Insights that students gained into their own learning processes were considered or discussed. When students are asked to "talk or write about their thinking, we are telling them that we value what they have to say . . .. By presenting what they think is important, students exercise great power and control over their leaning, that is, they become empowered" (Mumme & Shepherd, 1990, p. 19). Examples of student journal entries that support this observation include:

- "One thing that really helps is to have an open relationship with my teacher so that I will feel comfortable enough to be able to ask questions and get help on information."
- "I think the pace of the class is wonderful. I remember that last semester ... I always felt like I was drowning b/c I could not keep up with his lectures and homework. I really appreciate the way you kind of feel the class out and don't make us stick to the schedule all the time. It helps me a lot to not feel so pressured that I end up not learning anything."
- "The class is going way too fast ... Everything is a blur ... I hate graphing ... I really just hate math."

Wanting to be heard is a very suggestive aspect of sense making. When students are engaged in a discourse community, part of sense making is not just being inducted into the discourse community but actually participating in it. Learning to participate in a discourse community of mathematics means being able to talk about mathematics but also means being able to influence or change the discourse. In the e-journals and e-mails, students' voices were heard. Students were able to gain some reflective understandings and control of their own learning by being a part of or participant in a discourse community.

Roles and relationships. The e-journal communications built trusting and personal relationships as feelings and emotions were explored and expressed. The open lines of communication sometimes made the e-journal serve as a therapeutic tool. As students reflected and composed responses to e-journal prompts about their learning in mathematics, they conveyed their frustrations and their confusions as well. As students became aware of what they knew and did not know, they began to exercise some control over their own learning and began to feel the empowered.

The typical role of the teacher is to transmit information and the role of the student is to learn information. E-journals provided changes in the relationship when students perceived my role differently and their role in the learning process in a different way. How did my role change? I was still the center of the communications, the hub, but I may be now referred to more as a catalyst in providing the environment in which reaction can occur including that of self-reflection. Examples of student journal entries that support this observation include:

- I expect to fail that last test. I had studied ... but my mind was not focused. I have been having trouble with a girl and it is starting to disrupt my life. When I took the test, my mind was not focused and all I could think about was lying in my bed and crying or giving it up and going home.

- On the test I expected to make an A and I succeeded in my goal. To study for the test I went over all my homework and read through all the chapters that we covered to make sure that I didn't miss anything . . .. Going into the test I knew what my strengths and weaknesses were. For the next test I believe that I will . . .

- I feel like I did very well [on the exam], and successfully achieved my goal. For the next test, I am going to study more and know the stuff better

> because I feel like my main problem was the time restraint.... But aside from that, I am understanding the material and feel like I am doing well.

The fundamental nature of the e-journal allowed for the private conversation between the student and me. It provided a hotline in which I was able to really listen to each student individually as they described what they did or did not understand. E-journal responses provided a two-way path of communication, presenting me with the opportunity to "reflect on the teaching/learning process and to better meet the instructional needs of *each* [italics added] of the students" (Gordon & Macinnis, 1993, p. 41). Examples of student journal entries that support this observation include:

- "I just wanted to tell you that I'm not sure how I did on that test today. I thought that I really knew that stuff but I was really confused on some of the problems. Well, have a nice weekend. I'll see you on Monday."
- "I feel like we don't have enough class time. I'm having a bit of trouble."
- "What would really help me is if you could just go a little slower."

In conclusion, e-mail served as a conversational, instructional, and administrative tool. E-mails provided the students a conversational tool in which they were able to converse with me about problems in or out of class, check about homework assignments, or just talk. As an instructional tool, e-mails allowed me to discuss students' conceptual problems. E-mail also provided me with an administrative tool in which I could send changes in class times, assignments, or other organizational needs. While the use of e-mails as a conversational tool changed my role as a teacher, there are certain drawbacks to the changed role. In terms of time, reading e-mails and conversing with students on a personal basis through e-mail requires an immense expenditure of time and patience. Some professors may not consider the personal relationships appropriate. Because most of these students were freshmen, I considered a certain amount of "hand holding" to be a moral, caring undertaking.

E-journals provided an avenue for students to write as they reflected upon conceptual understanding and participated in the discourse community of the class, bridging the discourse community of mathematics. Additionally, the study supports the assertion that students' writing provides a starting place for change as teachers reflect upon how their students learn and think about mathematics.

Discussion Board and Virtual Chat

In the beginning, I planned on using Discussion Board as an avenue for discourse to build understanding of mathematical ideas and concepts through a more connected pattern of communication. Figure 3 shows a representation of communication patterns possible through Discussion Board. Notice there no longer is a central hub, but that all members of the community are able to communicate with each other.

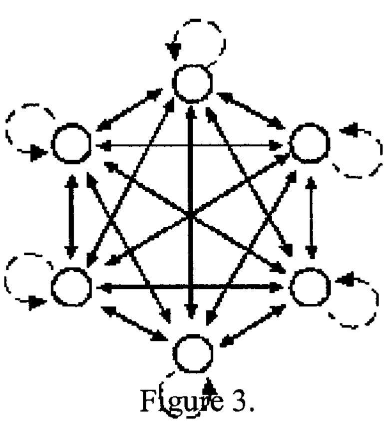

Figure 3.

While individuals still have opportunities to reflect, a discourse community may have a richer dialogue because of the interconnected and interactive nature of the relationships. Through the process of discourse, students participate in an interactive talking, listening, and negotiation of mathematical meanings. As students discuss mathematical ideas and communicate directly with each other, there "arises a common language of ideas that are shared, thus providing a basis for further communication" (Cassel, 2002, p.38). The interactive nature of the circular process allows students to continue the focus on the mathematical idea or meaning. "Ideas are 'placed out in the open' for all to try to make sense of and understand" (p. 38).

Lack of confidence may have been a reason the discourse community in Discussion Board did not evolve. Interviews of the ten students at the end of the semester revealed reasons why they did not feel comfortable using Discussion Board or Virtual Chat. [See the interview section that follows for details.]

There are some assumptions that I made about students engaging in the discourse community of Discussion Board. While a little surprising that so few students wanted to participate in the virtual community, it is not at all surprising and somewhat arrogant of me to think that students would want to enter a website to sit around and talk about mathematical concepts and ideas. Consider this in comparison: You attend a party with a lot of interesting people. The conversation shifts to gourmet cooking. Do you feel a part of this group? Are you comfortable in joining the discourse or are you a little intimidated or even a little uninterested? For me, being a part of this conversation means I immediately have nothing to add to the conversation, know nothing about gourmet cooking, including the language, nor do I have any interest in even listening to the conversation. My idea of gourmet cooking is to actually bake a cake from "scratch," not using a mix. This is probably how my students felt when asked to participate in a discourse on Discussion Board about mathematics. When students were asked how Discussion Board could be made more helpful to them, most politely replied they had no need for the forum. One student voiced her frustrations with her life and explained that, "I don't have time to sit and chat about math. I just barely find the time to do the homework." Trying to understand the position of the students and their feelings may help us to better understand why the Discussion Board did not evolve as expected.

Here are some reasons that I believe Discussion Board or Virtual Chat did not work for this group: Lack of confidence in their own abilities to function as a participant in the discourse community; lack of time and/or desire for a discussion of mathematical topics; and lack of mathematical symbols that made it difficult to write questions from students' homework. Several of these reasons were substantiated through the interviews conducted at the end of the semester.

Interviews

Interviews revealed little new information, but were excellent sources in the triangulation of the e-journal and e-mail data. Students did conclude that while they did not find the electronic technology to affect their learning much, they believed, like Peter, "As far as communication goes, there's nothing better between a teacher and a student." Students found the "online thing really helpful" to those who were uncomfortable and too shy to ask for help.

Interviews revealed why students like Jennifer were "lurkers" in Discussion Board or Virtual Chat. (A lurker is someone who enters an area, looks, watches the interactions, but does not participate[Zhu, 1998].) Jennifer admitted that Discussion Board "kind of intimidates me, because the way they answer it is much more clear than ... you know, we get the same answer but they can put it into words better than I can." As Scott talked about the problems with Discussion Board and Virtual Chat, he voiced feelings of shyness, " I feel stupid asking questions that a lot of people would know ... I've always never had the nerve to ask." Rachel avoided Discussion Board because she didn't "feel like I could get my question across, typing it."

Representing mathematical ideas electronically was a problem for several of the students. Another yet unexplored and recently emerging area of electronic representation is how electronic communications may ultimately change how we imagine mathematics. While this study has examined the effects of the new electronic technology upon communications in a mathematics classroom, a larger view compels us to consider the impact of computer images upon us as individuals as well as on our mathematics and culture.

The conflict between word and image

Shlain (1998) posits considerable circumstantial evidence linking the use of computer images, including photography, and electromagnetism, to right- and left-brain orientation and their ways of knowing. As he begins his argument, Shlain, a neural surgeon, describes the onset of use of the written word as a time of explosive change. While the changes are portrayed as progressive changes, the introduction of writing in its alphabetic form changed the culture from one with a feminine outlook to a male dominated outlook. The feminine outlook is depicted as a right brain or whole-brain view of the world illustrated with holistic, simultaneous, synthetic, and concrete viewpoints. Prior to the introduction of the written word, goddess worship, feminine values, and women's power were dominant in the culture. As the written word became central to a culture, the predominant thinking became more masculine: linear, sequential, reductionist, and abstract. As images of communication were replaced with the written word, patriarchy dominated.

In order to further posit his theory, Shlain (1998) describes the characteristics of the two hemispheres of the brain as they work closely in connection with each other. The right brain is nonverbal, comprehending the "language of cries, gestures, grimaces, cuddling, suckling, touching, and body stance. Its emotional states are under little volitional control and betray true feelings through fidgeting, blushing, or smirking" (p. 18). The right brain, more often than the left, produces analytic feeling-states such as love, humor, or aesthetic appreciation. "When people find it necessary to express in words an inner experience such as a dream, an emotion, or a complex feeling-state, they resort to a special form of speech called *metaphor* that is the right brain's unique contribution to the left brain's language capability" (p. 20). The right brain's primary attributes relate to being, images, holism, and music.

Shlain's (1998) descriptions of the left-brain characteristics are contrasted to those of the right brain. While the right brain is concerned with being, the left is focused on doing. Doing is concerned with action. Words are tools that are used to "abstract, discriminate, analyze, and dissect the world into pieces, objects, and categories" (p. 21). The key left-brain task of analysis depends upon linear progression that is in contrast to the holistic perception of the right brain. The features unique to the left-brain are linear: doing, speech, abstraction, and numeracy.

Shlain (1998) further argues that the printed word introduced the dominance of speech, abstraction, and numeracy. As the analytical and abstract came to be of more importance, the balance of power was altered to women's detriment. "Literacy has promoted the subjugation of women by men throughout all but the very recent history of the West. Misogyny and patriarchy rise and fall with the fortunes of the alphabetic written word" (p. 3). "Whenever a culture elevates the written word at the expense of the image, patriarchy dominates. When the importance of the image supersedes the written word, feminine values and egalitarianism flourish" (p. 7).

After World War II, photography and electromagnetism combined to introduce television in 1939 (Shlain, 1998). Few people realized that this was the beginning of the end of patriarchy as images began to prevail over written words. Comprehending television increased the power of images to the point that "iconic information has superseded alphabetic information as the single most significant cultural influence" (p. 409). Another product of the combination of photography and electromagnetism was the personal computer. The computer reinforced the perceptual mode of the right brain by converting the television screen from a monologue to a dialogue, thereby making it interactive. While handwriting involves only one side of the body, reducing right-brain participation, as individuals use of the computer to represent ideas, the left-brain dominance is superceded by whole-brain activity.

The perceptual mode of the right brain is strengthened through non-linear activities. Use of the computer's mouse involves skills using hand-eye coordination that are more spatial than linear and frees the right hand from staying within the lines while writing. Word-processing programs utilize another right-brain activity. Shlain (1998) states that the "geometrical moving about of phrases, sentences, paragraphs, and whole passages increased the right hemisphere's influence on the *composition* of writing" (p. 417). Linear thinking is further deterred because a computer has no pages to turn.

In this study, I described a new era in which electronic communications play a vital role. Shlain (1998) posits computer use has taken human communication to a new stage as important to humankind as the invention of writing. The implications of Shlain's claims suggest an intriguing new age of computer use in which the right-brain values provide more balance with those of the left brain in such a way that new hope for an egalitarian world exists. What are the implications for this new egalitarian world in which right brain attributes of caring, loving, synthesizing of elements all-at-once, and interpreting subtleties of conversation are balanced between the linear, logical, abstract, and analytical attributes of the left brain? What are the implications for mathematics and what we may soon come to consider as important mathematics for students to learn?

Implications

Use of electronic technology as described in this study may have the potential to assist in providing a balance and forum for mathematical conversations. My research focused upon how learning and classroom instruction were impacted by ubiquitous computer usage during the initial year of an implementation project to provide laptops and Internet access to all students. In this study, I examined the potential of the electronic technology to facilitate communications, develop relationships in the classroom, and explore mathematical thinking.

The changing relationships between the students and the professor suggest possible implications for teacher preparation and ongoing professional development. The current focus on achievement may contribute to students' feelings that we as educators do not really care about them but only care about them as products, supporting traditional factory models of an educated population (Noddings, 1992). Rather than focusing on particular learning theories, teacher methodologies, and knowledge of the subject matter, teacher education programs should encourage teachers to really listen to their students; to make caring connections with their students; and to provide an environment in which students are able to make sense of mathematics (Davis, 1997). As Doll (1993) suggests, our educational vision should include curriculum as a process in which "learning and understanding come through dialogue and reflection. Learning and understanding are made (not transmitted) as we dialogue with others and reflect on what we and they have said" (p. 156).

Electronic technology is a significant element in the enhancement of the interactive processes occurring between students and professor. The nature of the electronic communications allows for immediate, dynamic conversations in which relations of care and trust can be established outside of the public environment of the classroom. An important component of the electronic communications is the teacher's involvement in conversation with the students, giving advice, answering questions, and engaging them in the discourse community of mathematics. Electronic communications can be liberating. The inherently human need to communicate is much more easily achieved or supported through technology. Electronic technology encourages us to envision an entirely different way of representing and interacting with our world, promising a new emphasis on the way we make sense of our world—through images and metaphors.

While the electronic technology was a significant element in the enhancement of the interactive processes occurring between the students and me, certain limitations may need to be considered: (1) The impact of the amount of time needed to carry on significant and meaningful conversations took a considerable amount of time on a daily basis. While educators gain a wealth of student information and understanding of student sense-making, the time cost should be carefully considered. (2) Students include a lot of "garbage" with their responses in an effort to pad their e-journals when they feel insecure and uncertain about their ideas. However, if you can sift through the garbage, many times, you find valuable insights in the way students define their ideas and struggles in mathematics. (3) Student use of e-journals may diminish the classroom dialogue by providing another avenue for students to ask questions and probe for understanding. (4) While the Internet has a unlimited source of websites that are interesting to explore, researching the growing number of websites and locating ones that offer rich activities relating to the mathematics curriculum is often very time consuming. As the study began, there were a limited number of resources available for college algebra classes. This will change, as many new resources are being made available. (5) The primary technological tool that has been used extensively in the mathematics classroom for the last decade is the graphing calculator. The college algebra students in this study used the graphing calculator daily during class activities and for their homework assignments. Because there has been extensive research published regarding the use of the graphing calculator, in this study, I chose to ignore the use of the graphing calculator as it influenced the students' sense making. (6) At times, ease in communication may have masked the focus on mathematics either as students intentionally replaced the mathematical discourse with personal discussions or as the time of the instructor is taken away from the mathematical discourse by personal discussions. This is a balancing issue, as well as a comfort level, and the instructor must recognize when the teacher-student relationship is being violated, abused, or extended beyond either comfort or appropriateness levels.

Possibilities for Further Research

This research focused on the use of electronic technology as it impacts the communication patterns, roles and relationships among students and faculty, and the contributions to students' sense making of mathematics. One aspect of the study was to examine student writing as a response to prompts in e-journals. Since reading and responding effectively to the e-journal prompts requires a great expenditure of time, additional research needs to be conducted to analyze if student benefits are significantly greater in comparison to benefits of less intensive forms of communication. Of course, "benefits" as traditionally interpreted as "mastery" or "achievement" may also need to be examined as challenges to what is important mathematics for students to learn are addressed.

In addition, studies need to examine the effect e-journal writing activities have on the teacher's preparations, reflections about the course, and the use of language, imagery, and activities in the classroom. How do the changing roles and relationships affect the tone and mood of the classroom discourse? Do classes that are more inclined to ask questions through e-mail have less dynamic and rich class discussions? Additionally, further study needs to examine the effects of the use of nonverbal cues within online dialogue.

Additional research is needed to better understand the impact of e-mail and e-journal interactions. Research investigating the influence these types of interactions have on the students' intellectual development, attitude and performance could provide guidance to instructors using electronic course delivery mechanisms.

Vital to the efforts and desires for change in school mathematics is the wish for all students to succeed in understanding mathematics, regardless of their gender, status, or cultural background. Further research related to Shlain's theory of the influence of the computer image as it shapes our culture of writing needs to be addressed.

"The role of language in the development of mathematical understanding and in supporting problem solving in mathematics is uncharted territory" (Pugalee, 2001, p. 242). Further research needs to examine the language games and the emerging understandings that occur through the conversations between the students and the professor. Studies need to examine the extensive, back-and-forth negotiation of meaning and understanding as they evolve over an extended period of time. While it is not clear how electronic communications contributed to student sense-making in this study, as ideas and structures for mathematics curriculum, instruction, delivery, and assessment change, understanding the role of language and meaning as facilitated by electronic communications will be important. It is hoped that this study will encourage further research into the links between writing and language and the learning of mathematics.

Electronic communications using e-journals and e-mails provided an exciting, yet overwhelming experience for me. Even though I felt there were great rewards, I did not continue the e-journals during the two semesters since I conducted the study. However, I plan on attempting a modified version beginning in the fall. The opportunities for insight into student understanding and student reflection are too great to miss the opportunities to interact on an individual basis with each student.

Electronic communication is rapidly being integrated into the classrooms of the world. The government's *No Child Left Behind Act* is mandating requirements for the implementation of various technologies, training for teachers, and calling for states to wire their schools to the Internet. Computer access is necessary for students entering our universities today. Universities are providing E-mail accounts to all students and faculty members on campus. Experts are touting the enormous benefits that these connections provide. "As researchers, we need to provide the designers of learning environments with guidance on how to best position these technologies with the overall course and communication structure" (Kirkley, Savery, & Grabner-Hagen, 1998, p. 232).

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APPENDIX A

SURVEY QUESTIONNAIRE

The following pages contain the Survey given to the College Algebra students on the first day of class.

Name ______________

Survey Questions

1. What is your classification in school?
   Freshman Sophomore Junior Senior

2. What is your major? ____________________

3. What was your last mathematics class?
   Intermed. Alg H.S. Calculus H.S. PreCal H.S.Alg II Other ____

4. What was the grade you made?
   A B C D F

5. What was your score on the mathematics portion of the ACT?
   Below 20 21-24 25-28 29-32 33+

6. At what age did you receive your first computer?
   Before age 16 17-19 20+

7. Describe your experience with the following software. Check all that apply and state the level and kind of use.

______Microsoft Word Basic________________________________
______Microsoft Word Intermediate__________________________
______Microsoft Word Advanced____________________________
______Microsoft Excel Basic________________________________
______Microsoft Excel Intermediate__________________________
______Microsoft Excel Advanced____________________________
______PowerPoint Basic____________________________________
______PowerPoint Intermediate______________________________
______PowerPoint Advanced_________________________________
______Programming—In which languages? ______________________
____

8. Describe how you see yourself as a computer user.
   Hacker   Expert   Do what I need to do   Uncomfortable

9. Would you be interested in being interviewed? (Note: this will take around 30 minutes at the beginning of the semester and around an hour at the end of the semester.)____________

10. How do you hope to use the mathematics learned in this class?____

____

11. Typically, when you do math homework, do you
_________work alone
_________work in a small group
_________other, describe

____

12.How do you perceive your level of participation in math class?
_________uninvolved
_________silent observer
_________ask questions when I have them
_________ask questions to extend my understanding
_________discuss mathematical ideas
_________other?

____

13. How interested are you in mathematics?
_________not very
_________enough to get by
_________somewhat
_________very

14. What should be the role of the math teacher in helping you learn math?____

____

____

15. How do you prepare for a math test?________________________

____

____

16. Have you ever used the internet to help you with your math? ____
Describe.

17. How do you perceive or expect the use of computers may affect your learning in this class? My teaching?

18. What do you perceive to be the nature of the mathematics you will learn in this class?

APPENDIX B

E-JOURNAL PROMPTS

The following pages contain the e-journal prompts given to the students each week.

Appendix B

List of Journal Prompts

Wed, Jan 09, 2002 -- *Journal Entry #1*
Please talk to me about yourself and your mathematics. Let me know who you are, especially your feelings about mathematics.

If mathematics was a fruit, it would be a . . . because. . .

Tue, Jan 15, 2002 -- *Journal #2*
Describe the kinds of things that make it easier for you to learn mathematics.

What does the correlation coefficient tell us?

Sun, Jan 20, 2002 -- *Journal #3*
Describe a real-world situation that could be modeled by a function that is, in turn, increasing, then constant, and finally decreasing.

Tell me how things are going. Is the pace in class, too slow, too fast, or okay?

Find an interesting website for what we're doing to get bonus points.

Tue, Jan 29, 2002 -- *Journal Entry #4*
How do you expect the used of computers will affect your learning in this class?

Give me two examples for each of the three basic variations that we talked about in class: direct, inverse, and joint.

Tue, Feb 05, 2002 -- *Journal #5*
What did you expect to make on the last exam? What did you do to study for your last exam? Did you succeed in your goal? Is there anything that you will do differently for the next exam? Describe those changes, if there are any.

For those of you who have taken Intermediate Algebra, do you feel like Intermediate Algebra has prepared you thus far for this class? If so, how? If not, what are you lacking?

(Remember, this needs to be about 1/2 page. If yours is not, describe what your struggles are, what is happening with you, or whatever you think would help me to help you in this class.)

Tue, Feb 12, 2002 -- *Journal #6*
What are zeros? Describe them algebraically and graphically. What is their importance?

How can you tell the difference between a linear function and a quadratic function? What is the difference between the zeros for a linear function and those of a quadratic function?

How can Discussion Board be changed to better serve you and your needs? Is there a better time? a better . . . ?

Wed, Feb 20, 2002 -- *Journal #7*
Why is it necessary to check the possible solutions of an equation? What sort of rule of thumb could we use to know which ones to check and which ones I can "trust" that my answer is correct? (Checking the back of the book will NOT answer this question.)

What if I had to be at home for a week and sent you notes and had an open discussion during class time? How would you adapt? What would be the thing you could suggest to others to help them to learn and make sense of the concepts we were covering?

Tue, Feb 26, 2002 -- *Journal #8*
Describe how you factor a cubic equation quickly. (Quickly doesn't mean describe it quickly. Make sure you describe in detail what steps you would go through to find all the factors of a cubic equation.)

Tue, Mar 05, 2002 -- *Journal #9*
In chapter 4, we study about inverses. List some real-life inverses.
On our last test, some of you knew "what to do" but didn't understand what you were doing and when to do it. For example, synthetic division is a relatively simple thing to perform. Understanding it's use and purpose are the difficult parts. In light of these statements, what do you think it means to do mathematics?

Wed, Mar 13, 2002 -- *Journal #10*
I appreciate having my computer so that. . . (three of these and the reason why)

I know these last five weeks of school will be hectic so I plan to . . .

Tue, Mar 26, 2002 -- *Journal #11*
Describe a good experience that you have had using your computer in any class.

Describe the relationship between exponential and logarithmic functions.

Discuss examples of various kinds of exponential and logarithmic functions from the real world.

Tue, Apr 02, 2002 -- *Journal #12*
Explain in your own words when the elimination method for solving a system of equations is preferable to the substitution method.

Or:
Write a problem for a classmate to solve that can be translated to a system of three equations in three variables. Then show how to solve it.

Don't forget these need to be AT LEAST 1/2 page in length. You may answer one or both of the questions to make it long enough. :)

Mon, Apr 08, 2002 -- *Journal #13*
When multiplying two matrices, does A*B= B*A? Explain why or why not, using proper terminology and demonstrating with examples. Make sure that you put the most emphasis on "explaining."

Your best friend is taking this class next fall. What advice would you give him/her?

APPENDIX C

SURVEY RESPONSES

The following pages contain summaries of all the responses to the Survey given to the College Algebra classes on the first day.

Survey Questions/Responses for Morning Class

1. What is your classification in school?
   Freshman IIIIIIIIIIIII (13) Sophomore IIIIIIIIII (10) Junior Senior
2. What is your major? Elem Ed II_II Bio II CS II
   Relig Ed I Eng I
   Psychology IIII Music I ME I Fam Stud I
   und II EE I Gen Studies II
3. What was your last mathematics class?
   Intermed. Alg IIIIIIIII H.S. Calculus I H.S. PreCal I
   H.S.Alg II II Other I
   Elments of Math II II_III__ Hs Stats I College alg I
4. What was the grade you made?
   A IIII B IIII C II D I F I Pass IIIIII No response II

5. What was your score on the mathematics portion of the ACT?

Below 20	21-24	25-28	29-32	33+	No response
IIII	IIIIII	IIII	II		IIIII

6. At what age did you receive your first computer?

Before age 16	17-19	20+
IIIIIIIIIII	IIIIIII	II

7. Describe your experience with the following software. Check all that apply and state the level and kind of use.

IIIIIIIIIIIIIIMicrosoft Word Basic
_IIIII___ Microsoft Word Intermediate
IIIIII______Microsoft Word Advanced
_IIIIIIIIIIII_Microsoft ExcelBasic
__III___ Microsoft Excel Intermediate
__I___ Microsoft Excel Advanced
IIIIIIIIIIIII_PowerPoint Basic
__IIII__ PowerPoint Intermediate
__III_ PowerPoint Advanced
_IIIII__Programming—In which languages? C++ IIII_ html II basic II visual basic, II java, c javascript I misc and others
______Autocad I___________________________

8. Describe how you see yourself as a computer user.

Hacker	Expert	Do what I need to do	Uncomfortable
	IIIIII	IIIIIIIIIIIIII	

9. Would you be interested in being interviewed? (Note: this will take around 30 minutes at the beginning of the semester and around an hour at the end of the semester.)__

   yes IIIIIIIIIIIIII_________ no IIIII ? I

10. How do you hope to use the mathematics learned in this class?
    - For one, it is a part of my major, but I hope to be refreshed in my math skills so I can use it in daily life, as well as to help my children someday when I have a family
    - I need this basic knowledge for further math classes used in my major
    - I really hope to pass and hope I won't freak out when I hear the word "math."
    - Stuff in the real world—payments, taxes, etc.
    - I hope to achieve a greater understanding of algebra and do what it takes to master it.
    - Just to have the basic knowledge and know how to use it, if it comes up again!
    - Yes, I plan to take some high math classes so this will be a help to get me back into math
    - To pass this class and on the graduate record exam
    - To be an architect one day
    - In everyday life
    - I don't
    - I will use it so help me graduate and for my job.
    - Find a way to use it for your kids
    - Whereever and whenever necessary
    - Be able to teach others what I have learned
    - Math is needed in everything that you do.
    - Towards my career
    - Hopefully it will apply a lot to my life and job
    - Fulfill a requirement for my degree and acquire a basis from which to research
    - To further more math classes
    - To further my knowledge
    - To get enough understanding to complete trig

11. Typically, when you do math homework, do you
|||||||||||||||||||_____work alone
|||________work in a small group   sometimes alone though
__________other, describe
____

12.How do you perceive your level of participation in math class?
_____|_____ uninvolved
_||||________silent observer
||||||||||||||||__ask questions when I have them
||||||_______ask questions to extend my understanding
|__________ discuss mathematical ideas
__________ other?

13. How interested are you in mathematics?
_||||_|______not very
__||||______ enough to get by
_|||||||||_____somewhat
_||||_______very

14. What should be the role of the math teacher in helping you learn math?

- Make sure I understand before moving on; work lots of example problems.
- I would hope that she would be able to further explain ideas that I do not understand so that I can complete my work.
- To help students fully understand and make things clear.
- Eager on the subject; willing for out of class help
- Be clear in what we are learning about. Be patient and helpful.
- Have time to help me individually when and if I need it
- Explaining how a formula or equation works—give examples and show steps Then let us ask questions.
- Explaining problems clearly and alternate ways of doing them. Help students understand.
- Helping the student to understand order, reason, how to solve problems
- The teacher should be interested in math, and patient enough to explain it.

- To teach thoroughly ideas that are to be on test, as well as cover info not on test
- Answering questions and explaining math concepts and formulas clearly
- Go through the steps to solve the problems and is available for help. Also keep up with blackboard.
- Teach in a way that everyone understands and have more of a connection with the students than strictly teacher/student
- They must help to understand concepts, but attempt to let the student do the work.
- A math teacher should raise questions in the minds of the students that they need to find the answers.
- An actual teacher not on who just give lectures. And also one who doesn't mind explaining thoroughly.
- To effectively transfer the knowledge and capability to perform algebraic equations
- Show it to me, test me
- Answering questions I don't understand
- Being able to do the work he/she assigns
- Keep us updated on our grades, and be around when we need help

15. How do you prepare for a math test?
    - Work problems and review formulas
    - I have never had to study for a math test before, but I am open to any new methods of studying.
    - Go over notes, do some math exercises to review
    - Study by redoing problems
    - Review previous problems and rework them for more practice.
    - Look over notes...but I really don't know how to study for math tests
    - Review formulas and go over old equations from homework.
    - Look over past homework assignments and study them.
    - Review any misunderstandings and check out previous work
    - I do practice problem, make sure I understand all the concepts.
    - Do review problems
    - Look over past work

- Do the review
- Study
- Do the review
- I work problems until I am comfortable with them. I do have problems with tests anyway for reasons unknown to me.
- Working problems and looking at notes and examples.
- Work practice problems
- Pay attention in class, do the required assignments
- Do homework assignments
- Look over old assignments and make sure I knows the formulas needed
- I'm still learning this

16. Have you ever used the internet to help you with your math?
No IIIIIIIIIIIII__________ Describe.
______ Yes—Aleks IIIII
Yes-to look up formulas
Yes—websites have formulas and math problems explained

17. How do you perceive or expect the use of computers may affect your learning in this class? My teaching?
    - I haven't really thought about it, so
    - I was wondering how a computer could be used to do math, so I am very interested in beginning your class.
    - Computers-not really other than the calculator in the start menu. I hoe you will help be get a better grasp on math and how it works.
    - I think computers would make it more frustrating and harder. Math is my worst subject alone; I already fear this class.
    - I would rather learn from a professor than from a computer. I am hot a huge computer fan.
    - I don't think it would have a bad affect, its just not as easy to understand.
    - I really don't know, I have never used my computer for math. I like working things out on paper to do the steps—I will have to see.

- Use tools to understand math problems or learn different ways to teach them
- I have no clue. E-mail is used as much that makes it difficult for me. I live off campus with 4 people. It is not always possible to check my mail.
- I don't know.
- It will be interesting.
- It should improve both
- I only see the use of the computer in this class to be with blackboard
- I hope that it can help me.
- I am not really sure yet.
- Sometimes a different point of view can make a problem more clear. We don't all approach a problem the same way.
- ?
- not much...I think its hard to translate computer use to an algebra class
- I expect that beyond use as a calculator, the computer will likely cause more trouble than it is worth.
- I just don't know
- I think that both will only help
- It will be easier t see our grades, and the math web sites can help.

18. What do you perceive to be the nature of the mathematics you will learn in this class?

- basic algebra principles
- An extension of hs algebra
- I have no idea-algebra and geometry?
- Mostly important and detailed aspects of algebra
- Everything I need to know
- I have taken this course in high school and I will have to be refreshed with the equations, but for the maj part it will be a review
- Algebra levels 1, 2, 3
- Simple algebra
- Advanced algebra
- Algebra I've learned before, maybe some new stuff
- Algebra that I have done before and am relearning

- Algebraic equations
- I like to know why things are the way they are because God used math to create and give the knowledge to his children.
- College level algebra
- Algebraic? Easy?
- Rudimentary algebraic functions neither advanced nor complex
- An extended awareness of college algebra
- Challenging
- Critical thinking

Female IIIIIIIIIII (11)   Male IIIIIIIIIIII (12)

Survey Questions/Responses for Afternoon Class

1. What is your classification in school?

Freshman	Sophomore	Junior	Senior
IIIIIIIIIIIIII (14)	IIIIII (6)	III (3)	I (1)

2. What is your major? Science II CS I

Bio III Psy III

Fam Studies II Secondary Ed I elem ed IIII Comm II

und III Bus I

3. What was your last mathematics class?

Intermed. Alg	H.S. Calculus	H.S. PreCal	H.S.Alg II	Other
IIII	III	III	IIII	IIIIIIII

4. What was the grade you made?

A	B	C	D	F	pass
IIIIIIIII	IIIII	II	II		III

5. What was your score on the mathematics portion of the ACT?

Below 20	21-24	25-28	29-32	33+
IIII	IIIII	IIIIIIIII	II	

6. At what age did you receive your first computer?

Before age 16	17-19	20+
IIIIIIIIIIIIII	IIIIII	II

7. Describe your experience with the following software. Check all that apply and state the level and kind of use.

IIIIIIIIIII___Microsoft Word Basic
IIIIIIIII__ Microsoft Word Intermediate
_ IIIIIIIII____Microsoft Word Advanced
_ IIIIIIIIIII___Microsoft Excel Basic
IIIIIII___ Microsoft Excel Intermediate
IIII_____ Microsoft Excel Advanced
_ IIIIIIII___ PowerPoint Basic
_ IIIIIIII___ PowerPoint Intermediate
_ IIII____ PowerPoint Advanced
__I___ Programming—In which languages? C++
I _ None of the above.______________________________

8. Describe how you see yourself as a computer user.

Hacker	Expert	Do what I need to do	Uncomfortable
	III	IIIIIIIIIIIIIIIIII	I

9. Would you be interested in being interviewed? (Note: this will take around 30 minutes at the beginning of the semester and around an hour at the end of the semester

Yes IIIIIIIIII no IIIIIIIIIII ? I

10. How do you hope to use the mathematics learned in this class?__
    - I have an assoc in electronic engineering so math is now my life and will use it to find solutions
    - Use it in computer programming
    - I guess to help children when I am tutoring at central. Not much else in my field except stats for research.
    - My algebra teacher in high school said math give you common sense.
    - I don't plan on using it; this is my last math requirement.
    - Use it to help others when I become a teacher
    - Gain a stronger base for higher level math courses
    - To not lower my GPA, fulfill gen-ed requirements and help me as I'm out on my own with
    - To finish college and that's it!!
    - I'll be a psych major and only plan on using the program SPSS.
    - In real life and science class
    - Financial planning and other everyday needs
    - Be able to apply it to everyday use.
    - I want to go on to calculus so I can have a better resume for med school.
    - This class will refresh my memory of work done in hs. It will be used to prepare me as a teacher.
    - I hope to gain an understanding of everything learned so I can apply it in appropriate situations.
    - Working a cashier
    - I want to be a doctor so however they'll be helpful!
    - To teach fourth graders
    - I hope to be able to use it to help with my job, and other maths I will take.

- I hope to understand and be able to use this in other classes.

11. Typically, when you do math homework, do you
_|||||||||||||||||__work alone
_||||||_______work in a small group   sometimes
__||_______ other, describe   usually <u>always</u> need one on one help.

I work along as far as I can and then meet with a small group of peers.

12.How do you perceive your level of participation in math class?

__________ uninvolved
_||_______ silent observer
_||||||||||||||||||_ask questions when I have them
_||||_________ask questions to extend my understanding
__________ discuss mathematical ideas
__________ other?

13. How interested are you in mathematics?
__|||_____ not very
_ ||||||_____ enough to get by   I would be more interested if I could actually understand it.
__|||||||||||__ somewhat
_ ||_______ very   I am using this as a GRE reviews in some ways.

14. What should be the role of the math teacher in helping you learn math?

- Explain concepts to the understanding of class and help whenever needed by students
- Clearly showing me step by step how the problem solved
- Fully explain methods by which you work the problems.
- Please don't assume or expect us to know certain things. I need a thorough explanation
- Teach me to effectively solve the problems.
- They should be a guide

- Teaching me not just the principle lesson but the entire concept so that I can have a better understanding.
- She should be able to help people at all different levels and explain in different ways so everyone can understand.
- Make sure that everyone catches on—I HATE it when some people are clueless and the teacher moves on.
- The teacher should help you with any questions.
- Explain clearly during class and be available for help outside of class.
- Teach me how to do certain things and apply them to real life.
- Explain all the steps
- Be understanding
- To teach us how to do the problems and how to become better problem solvers.
- Explain in class and be available to help outside the class.
- Be available for talking and answering questions outside of class.
- Teaching it to you
- I like when the teacher works through the processes with me, making and correcting mistakes I might have.
- Being able to explain lessons clearly
- They should be there to teach and help. I have to do the rest.
- I need one on one when I have problems.

15. How do you prepare for a math test?
    - Self quiz of use past homework papers to study from
    - Remember the formulas and the example
    - Do my homework. And problems similar to homework.
    - Do problems and go over my notes.
    - Look over my notes; d problems from each section I'll be tested over.
    - I look over my homework and worksheets from class and review the book, and work on problems from the book.
    - By studying homework and notes.
    - Rework practice problems over and over.
    - I've never had to.
    - Review notes, review problems on homework

- Review notes, homework, have a written list of what should be on this test that I should know how to do.
- Study and re-work previous problems.
- Go over equations that I need to memorize and as long as I have done all the homework I am fine.
- Study notes and re-do problems that I don't understand.
- Go over old homework and do sample problems in the book.
- Work to understand the concepts. Start working several weeks before the test.
- Go over and through problems that I don't understand -review the rest.
- I don't
- I work tons of sample problems. Just lots of practice!
- Do the review section at the end of the chapter.
- I redo homework.
- Review problems.

16. Have you ever used the Internet to help you with your math?
No IIIIIIIIIIIIIIII not really I only looked for some equations
Describe.

Yes aleks-- However I didn't like it.

Aleks we used aleks the oline program and it was not at all helpful to me because I need one-on-one help. The computer didn't teach me anything.

Yes-I use IM to have people explain how to do it.

Yes-you can post questions and get help with math ideas and concepts or general rules.

Yes last semester in Elements of Math I and II

17. How do you perceive or expect the use of computers may affect your learning in this class? My teaching?

- If work as class work or homework must be done on them I've found myself to be slower. I'm much much faster w/ pencil and paper.

- In fact, I don't think it is good to use computer to help thinking, but I agree that some math questions is very trouble that need help from pc. But before I go to the pc I will still try using my mind.
- I have no idea-my classes in psychology have typically not used the computer at all.
- I'm not sure.
- My Ti-85 and I get along great. I know I will have a lot of questions and I'm a hands-on learner, so I'll be spending lots of time with you I'm sure.
- I think that it will not affect my learning buy may help when teachings as a way to show examples of various problems.
- It will confuse me.
- I'm sure it will help people learn excel better and improve our computer/math knowledge
- It could be useful to be able to look at something that you had taught when I am studying.
- I don't know what to expect in this class, I hate bringing my laptop to class. The only math program I know and use is SPSS.
- It will be easier to get help with problems.
- I don't know.
- I really don't know.
- Computers will take away some attention, but will not affect the class that much.
- I don't expect it to change much. Perhaps the use of visuals by the teacher.
- Help me to keep my notes organized—calculator will help very much.
- None
- The computers keep us informed and help us remember ideas through searching.
- I believe it will help me somewhat depending on the section/topic.
- I don't think I twill be any different than most math classes. I don't believe it will effect the teaching either.
- When I learn to use my laptop I hope it will help me out.

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18. What do you perceive to be the nature of the mathematics you will learn in this class?

- Basic algebra is foundation.
- Yes.
- Pretty basic algebra
- A lot like algebra I and II from hs.
- Pretty much basic higher algebra. I took this class in high school.
- Formulas and graphing from the book.
- Background for higher math classes.
- Basic; basic fill in the "x=" questions.
- A review of things I learned in high school
- No idea what to expect. It's been a long time since I've taken a math class.
- ?
- basic math
- That it won't be too hard, but that there will be things that I don't know
- Basic foundations
- I expect it to refresh previous information.
- E=mc^2
- Graphing, algebra equations.
- I don't really know—I guess—to help me be a better teacher.
- I don't know, but I'm up to anything.
- I am hoping it will be come useful.

Female IIIIIIIIIIIIIIIII (17) Male IIIIIII

(7)

APPENDIX D

COMPILED DATA of RESPONSES

The following page is spreadsheet containing a numerical listing of the number of responses to each type of data by week.

Number of Responses by Week

Wk	1		2			3			4			5			
	#1	email	#2	email	disc	#3	email	disc	#4	email	disc	#5	email	disc	
Morning	16	4/4	12	15/8	1	12	7/4	4	11	10/6	0	10	7/7	1	
Afternoon	19	5/2	16	16/8	0	14	5/2	1	16	2/2	1	17	4/3	3	
Wk	6			7			8			9			10		
	#6	email	discus	#7	email	disc	#8	email	disc	#9	email	disc	#10	email	disc
Morning	7	11/8	0	9	4/3	0	11	13/7	0	11	2/2	1	11	12/7	0
Afternoon	11	4/4	2	11	3/3	2	9	8/5	0	18	7/5	0	11	6/5	0
Wk	11			12			13			14		15			
	#11	email	disc	#12	email	disc	#13	email	disc	email	disc	email			
Morning	6	3/3	4	7	14/6	4	5	13/4	0	20/7	0	12/7			
Afternoon	10	6/3	1	8	7/3	0	12	12/3	0	9/6	3	3/3			

- The columns labeled with the pound sign and a number refers to the e-journal number. See Appendix B for a comprehensive listing of the prompts.
- The column labeled email has a number representing the number of emails received followed by the number of different students who sent the emails.
- The column labeled disc represents the number of students participating in Discussion Board/Chat Room for the specific week.

APPENDIX E

SAMPLE INTERVIEW QUESTIONS

The following pages contain sample interview questions used for the initial in-depth interview and the final in-depth interview.

Initial Interview Questions

1. When did you receive your first computer?
2. Describe how you have used the computer.
3. Do you go surfing on the Internet? How often?
4. Have you ever entered a chat room or done instant messenger? How frequently?
5. When do you generally do these?
6. How frequently do you IM?
7. What do you think about IM'ing during class?
8. What mathematics did you take in high school? In college?
9. Describe your favorite mathematics teacher.
10. Why was this your favorite teacher?
11. What is the most enjoyable thing you remember about your previous mathematics classes?
12. What did you dislike the most?
13. Describe yourself as a math student.
14. How would your math teachers describe you? Why?
15. What do you expect College Algebra to be like? Why?
16. How do you study for mathematics?
17. How much time do you expect to spend studying for this class?
18. Describe the kinds of things that make it easier for you to learn?
19. Describe things that interfere with your learning?
20. How do you typically do math homework? When do you do math homework?
21. Describe your participation in math class.
22. Why are you taking this class? What do you hope to gain from this class?
23. Have you participated in posting on discussion board in another class? How frequently did you post? Why or why not?
24. Have you ever had a study partner? If so, describe how it worked.
25. Have you ever used the Internet to help you with your math? Describe it.

Final Interview Questions

1. How do you feel about the laptop program?
2. What do you like the most?
3. What do you like the least?
4. Explain your study activities for this class. How do you study? When do you do your homework? How? With whom? Describe.
5. Do you use your computer to get help on your homework? How? Describe.
6. Describe how the use of the computer has affected your learning in College Algebra.
7. In what ways, did you find the use of the computer helped you in College Algebra? The graphing calculator?
8. In what ways, did you find the use of the computer made it more difficult to learn? The graphing calculator?
9. How do you feel about using discussion board? How could it be made more helpful?
10. How frequently do you view the discussion board?
11. How frequently do you post on the discussion board? Why or why not?
12. How frequently do you participate in "virtual office hours?" Why?
13. What parts of the Blackboard software did you use?
14. How were you able to use the Blackboard software?
15. What part of the software was the most helpful? How did it help you?
16. What part was the least helpful? In what way?
17. Did anything interfere with your learning? In what way?
18. Describe the ways that the computer use was the most beneficial for you.
19. Describe your mathematical development during this class.
20. What was your primary learning tool?
21. If you had to retake this class, what would you do differently?
22. If your best friend were about to take this class, what advice would you give?
23. How has this semester been different from previous semesters of math classes?
24. Will this semester's experience change the way you study in the future? Why or why not?

25. Did having access to the professor have any effects upon your self-confidence in mathematics?
26. If your computer were taken away tomorrow, how would your life change? In college algebra?

APPENDIX F

INFORMED CONSENT

The following page is the Informed Consent given to each of the students on the first day of classes.

Informed Consent Form

This document is an informed consent form to participate in a research project entitled The Use of Computers on the Mathematical Understandings of College Algebra Students.

This project is a study exploring the use of computers on the mathematical understandings of college algebra students by Phyllis Bolin. The research is being conducted under the auspices of the University of Oklahoma-Norman Campus. The faculty sponsor is Dr. M. Jayne Fleener.

I am investigating the communicative patterns and relations among the meanings students construct through the use of computers in college algebra classrooms. The study will begin in November 2001 and conclude by December 2002. A survey and pre-test will begin the study. The results of the survey will enable the selection of twelve students for the interview portion of the study. An initial interview lasting around 30 minutes and a final interview lasting around an hour will be a part of the data for the study. These conversations will be audio taped and transcribed. You will be asked questions:

1. to identify your experiences and attitudes about mathematics and the use of computers,
2. to determine the learning strategies afforded through the use of computers in your learning of mathematics,
3. to determine whether the communicative process afforded through the use of computer email, virtual office hours, and discussion boards assists in your learning of mathematics.

Weekly journal entries and discussion board submissions will be included as a part of the study. The study will conclude with a post-test. At no time in the study will your responses to journal postings or interview questions affect your grade in the class.

This study holds no foreseeable risks. Your participation will greatly enable educators in their work to improve the learning activities in mathematics classrooms through the use of computers. You may gain insight from participation in the study through discussion of your understanding in mathematics. The study may also benefit your understanding through the use of technology.

Your participation is strictly voluntary, and all information given in the conversations and submissions will be held in strict confidence. Refusal to participate will involve no penalty or loss of benefits. You may withdraw at any time without penalty. You must be 18 years or older to participate. All information from this study will be kept in a secure location by the principal investigator. You may decline answering any questions in the interviews.

As a participant, you will not be identifiable from the data collected. A pseudonym will be used in the place of your actual name. Data will be locked away from non-project personnel and will be destroyed when no longer needed. Project publications will not allow for identification of individual participants. Audiotapes will be stored in a locked cabinet in a secure room.

I hereby agree to participate in the above-described research. I understand my participation is voluntary and that I may withdraw at any time without penalty or loss of benefits.

Please initial all the blanks below that apply and sign your name on the line.

_____ Yes, I will participate in the study and grant permission to use archived information from journal entries and discussion board postings in the study.

_____ Yes, if selected, I will participate in two in-depth interviews and grant permission to audio tape these interviews for use in the study.

_____ No, I do not grant permission for any journal or discussion archives to be used in this study and I do not wish to participate in the interviews.

____

Name ______________ Date

If you have any questions, please contact:

Phyllis Bolin
Principal Investigator
Phone: (405)359-5016

M. Jayne Fleener
Faculty Sponsor
Phone: (405) 325-1081

Contact the Office of Research Administration at (405) 325-4757 for questions regarding the rights of research participants.

APPENDIX G

E-JOURNAL PROMPTS

AND ITEMIZED NUMBER OF RESPONSES

The following pages contain the e-journal prompts with the total number of responses to each prompt.

Journal Prompts and Itemized Number of Responses

Wed, Jan 09, 2002 -- *Journal Entry #1*
Please talk to me about yourself and your mathematics. Let me know who you are, especially your feelings about mathematics.

If mathematics was a fruit, it would be a . . . because. . .

Number of responses: 35

Tue, Jan 15, 2002 -- *Journal #2*
Describe the kinds of things that make it easier for you to learn mathematics.

What does the correlation coefficient tell us?

Number of responses: prompt 1: 27; prompt 2: 26

Sun, Jan 20, 2002 -- *Journal #3*
Describe a real-world situation that could be modeled by a function that is, in turn, increasing, then constant, and finally decreasing.

Tell me how things are going. Is the pace in class, too slow, too fast, or okay?

Find an interesting website for what we're doing to get bonus points.

Number of responses: prompt 1: 19; prompt 2: 19

Tue, Jan 29, 2002 -- *Journal Entry #4*
How do you expect the used of computers will affect your learning in this class?

Give me two examples for each of the three basic variations that we talked about in class: direct, inverse, and joint.

Number of responses: prompt 1: 27; prompt 2: 27

Tue, Feb 05, 2002 -- *Journal #5*
What did you expect to make on the last exam? What did you do to study for your last exam? Did you succeed in your goal? Is there anything that you will do differently for the next exam? Describe those changes, if there are any.

For those of you who have taken Intermediate Algebra, do you feel like Intermediate Algebra has prepared you thus far for this class? If so, how? If not, what are you lacking?

(Remember, this needs to be about 1/2 page. If yours is not, describe what your struggles are, what is happening with you, or whatever you think would help me to help you in this class.)

Number of responses: 27

Tue, Feb 12, 2002 -- *Journal #6*
What are zeros? Describe them algebraically and graphically. What is their importance?

How can you tell the difference between a linear function and a quadratic function? What is the difference between the zeros for a linear function and those of a quadratic function?

How can Discussion Board be changed to better serve you and your needs? Is there a better time? a better . . . ?

Number of responses: prompt 1 and 2: 18; prompt 3: 17

Wed, Feb 20, 2002 -- *Journal #7*
Why is it necessary to check the possible solutions of an equation? What sort of rule of thumb could we use to know which ones to check and which ones I can "trust" that my answer is correct? (Checking the back of the book will NOT answer this question.)

What if I had to be at home for a week and sent you notes and had an open discussion during class time? How would you adapt? What would be the thing you could suggest to others to help them to learn and make sense of the concepts we were covering?

Number of responses: prompt 1: 22; prompt 2: 22

Tue, Feb 26, 2002 -- *Journal #8*
Describe how you factor a cubic equation quickly. (Quickly doesn't mean describe it quickly. Make sure you describe in detail what steps you would go through to find all the factors of a cubic equation.)

Number of responses: 20

Tue, Mar 05, 2002 -- *Journal #9*
In chapter 4, we study about inverses. List some real-life inverses.
On our last test, some of you knew "what to do" but didn't understand what you were doing and when to do it. For example, synthetic division is a relatively simple thing to perform. Understanding it's use and purpose are the difficult parts. In light of these statements, what do you think it means to do mathematics?

Number of responses: prompt 1: 21; prompt 2: 25

Wed, Mar 13, 2002 -- *Journal #10*
I appreciate having my computer so that. . . (three of these and the reason why)

I know these last five weeks of school will be hectic so I plan to . . .

Number of responses: 22

Tue, Mar 26, 2002 -- *Journal #11*
Describe a good experience that you have had using your computer in any class.

Describe the relationship between exponential and logarithmic functions.

Discuss examples of various kinds of exponential and logarithmic functions from the real world.

Number of responses: prompt 1: 9; prompt 2: 9

Tue, Apr 02, 2002 -- *Journal #12*
Explain in your own words when the elimination method for solving a system of equations is preferable to the substitution method.

Or:
Write a problem for a classmate to solve that can be translated to a system of three equations in three variables. Then show how to solve it.

Don't forget these need to be AT LEAST 1/2 page in length. You may answer one or both of the questions to make it long enough. :)

Number of responses: prompt 1: 15; prompt 2: 0

Mon, Apr 08, 2002 -- *Journal #13*
When multiplying two matrices, does A*B= B*A? Explain why or why not, using proper terminology and demonstrating with examples. Make sure that you put the most emphasis on "explaining."

Your best friend is taking this class next fall. What advice would you give him/her?

Number of responses: prompt 1: 9; prompt 2: 9

APPENDIX H

Mobile Computing Program

The following pages contain the background material for Oklahoma Christian University's mobile computing program.

Mobile Computing
Program for Oklahoma Christian University

The Mobile Computing Program at OC is being launched as part of a strategic initiative called the eCampus project. The concise vision statement for this project is provided below along with additional explanations of each bullet point.

eCampus Vision Statement

The eCampus project will provide a personalized, technology-enriched "OC experience" with anytime, anywhere access to all university constituents in order to:

. Enhance Student Learning.
. Extend Communications.
. Enable Student Services.
. Engage Campus Constituents.
. Encourage Information Literacy.
. Empower Students for the Future.
. Enhance OC's reputation.

Enhance Student Learning

OC seeks to be a place where students are educated from a foundation of a Christian faith "to think, communicate, and act in a complex, demanding and changing global community." Through the creation of new learning activities and hybrid courses the e-campus tools will enhance the core curriculum and many of our professional programs and will provide tools that will improve the student's ability to think, act and communicate in the information age. Evaluation of these new activities should be based on the Seven Principles of Good Practice in Undergraduate Education developed by Chickering and Gamson in 1987. These principles are:

. Encourage student-faculty contact
. Encourage cooperation among students
. Encourage active learning
. Provide prompt feedback
. Emphasize time on task
. Communicate high expectations
. Respect diverse talents and ways of thinking.

Extend Communications

The e-campus tools will provide personalized contact that starts with the first recruiting contact and extends through the life of an alumnus. Communication tools & information will also be available for other campus constituents (parents, donors, churches, missionaries, friends.) Communication tools will also extend the classroom by allowing faculty-student and student-student interaction outside the normal classroom hours.

Enable Student Services
Students should be able to access more and more of their information on-line. Routine transactions should be able to be conveniently completed on-line. This will allow students and alumni to have a more successful and satisfying OC experience and continue to use these services as alumni.

Engage Campus Constituents
All campus constituents should be able to take advantage of these on-line services and information tools. Several groups need to be engaged in a personalized experience with
OC using these tools to produce a more satisfying OC experience. These groups include:
. Future Students
. Current Students
. Former Students
. Parents
. Employees (Faculty & Staff)
. Donors
. Churches
. Missionaries

Encourage Information Literacy
Students need to know how "to communicate effectively using the tools of the information age." OC should be providing students with the skills needed to operate in a world filled with technology, but should also provide students with the intellectual tools to effectively process information. Information literacy requires that students be able to "recognize when information is needed and have the ability to locate, evaluate, and use effectively the needed information."

Empower Students for the Future
Students graduating from our institution will be required to live and work in a world of pervasive technology. OC students who have experienced the e-Campus should have an advantage in the marketplace over those students who have not had a similar undergraduate experience.

Enhance OC's Reputation
OC has a history of leading in the use of educational technology. The Mabee Learning Center in the 1960s and 1970s pioneered the use of technology for teaching and learning. OC seeks to extend and enhance that reputation by leading the way in the use of mobile computing to enhance the university experience.