10-22-2007

Developing Technological Pedagogical Content Knowledge in Preservice Teachers through Microteaching Lesson Study

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DEVELOPING TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE IN PRESERVICE TEACHERS THROUGH MICROTEACHING LESSON STUDY

By

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A Dissertation submitted to the
Department of Middle and Secondary Education
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

Degree Awarded:
Fall Semester, 2007

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This dissertation is dedicated to my family:

To my husband Dale,

who both encouraged me to pursue a dream

and then accepted my devotion to it,

and who offered the right words of advise

at precisely the right times;

To my children Rob and Julie,

who continue to serve as inspirations;

To my mother Jewell, for her continuous encouragement

and understanding throughout the entire process;

And in memory of my dad Roland,

as I continue to strive to make him proud.

ACKNOWLEDGEMENTS

I would like to take this opportunity to express my appreciation to the people who have helped me pursue this degree and write this dissertation.

To Dr. Maria Fernández, thank you for your support both personally and academically, for your understanding when life got hectic, and for all your advice in the research process.

To the members of my committee, Dr. Kenneth Shaw, Dr. Leslie Aspinwall, Dr. Elizabeth Jakubowski, and Dr. Alysia Roehrig, thank you for your time, your advice and your continued support.

To the student/future-teacher/friends who agreed to participate in this project, and then followed through with the commitment, thank you for sharing your time, your thoughts and your suggestions. I hope that when you look back on the project you will find the time well spent.

To Dr. Lou Cleveland, Brenda Alford, Charlene Lord, and the faculty and staff at Chipola College, thank you for both your personal and financial support, for your understanding and encouragement, for allowing my absence to attend classes, and for giving your permission for my research to be conducted on the Chipola campus.

To Lou and Betty Bender, thank you for both the financial support through your endowed scholarship, and the encouragement offered so that I did not stop with A.B.D.

To Dr. Kathy Shafer, thank you for your encouragement and for sharing your knowledge and expertise to help with coding the data.

To Amie Myers, thank you for offering suggestions that have made the finished product more professional, well documented, and easier to read.

And finally, to Matt, Rebecca, Calandra and all the doctors and doctoral candidates in the program, thank you for allowing me to be part of your lives for the past three years.

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ABSTRACT

This research study was conducted to explore the development of technological pedagogical content knowledge (TPCK) in preservice teachers as they participated in microteaching lesson study (MLS). Participants were six preservice teachers enrolled in the required technology course for mathematics and science teacher education at a small rural college. The researcher was also the instructor for the course.

The TPCK framework, modeled by Mishra and Koehler (2006) as three overlapping circles, focuses on the interrelationships between the three components of technology, pedagogy and content, and involves an awareness of the effectiveness of incorporating a technological tool in a content lesson. In microteaching lesson study (M. Fernández, 2005), preservice teachers worked in small groups through repetitive cycles of teaching, reflecting, and modifying a group lesson. Teaching to a group of students enrolled in a college mathematics class provided a situated learning environment for the preservice teachers to experience teaching with technology.

Data were collected qualitatively via audio and video recordings, observations, interviews, and course documents. Data analysis was conducted using the TPCK framework in conjunction with various state and national standards related to the three components of TPCK. Findings indicate that the preservice teachers developed an awareness of the nuances of teaching with technology in a student-centered learning environment, recognizing that traditional "methods" of teaching such as sequencing, pacing and written directions took on special characteristics when technology was involved. Factors seen to have an influence on the preservice teachers' decisions related to the use of a technological tool included participation as students in modeled lessons, comfort level, and the preservice teachers' beliefs related to learning and teaching with technology.

Preservice teachers also expanded their views on mathematical knowledge. Prior to the MLS process, the preservice teachers focused on technology used at a procedural level to "do the math faster," while post MLS data indicated a shift towards a more conceptual view of technology enhanced mathematics. One fringe benefit recognized by the preservice teachers was the experience of working with their peers in fine-tuning a lesson to maximize student learning, gaining practical experience applicable toward future school-based instruction.

CHAPTER 1
INTRODUCTION

Background

I begin this document by describing the role of the researcher so that the reader may become familiar with the setting in which the research study took place. In doing so I will briefly introduce the constructs related to the research topic, but refer the reader to the review of the related literature and the documented references for a more detailed description.

After teaching middle and high school mathematics for 17 years, I moved to a community college where I taught mathematics for another 9 years. At that time the community college was granted approval to begin offering baccalaureate degrees in middle and secondary mathematics and science education, and officially became a college. I continued teaching mathematics at the community college level, but based on my interest in technology, I was also asked to develop and teach a college-level course on Integrating Technology in the Classroom; this class was developed to prepare our future teachers for the technologically advanced atmosphere in which they will work.

Around that same time I entered a Mathematics Education doctoral program. When given an opportunity to research a topic of my choice, I elected to research the field of technology in teacher education. I began to realize that the course I had developed and taught for two years needed some improvement. Through various projects I researched and documented the importance of modeling as a strategy in teacher education (Cavin, 2006a), as well as the importance of providing opportunities for future teachers to experience teaching with technology (Cavin, 2006b; Cavin & Fernández, 2007).

I also began reading about the recently introduced construct of technological pedagogical content knowledge (Keating & Evans, 2001; Mishra & Koehler, 2006; Niess, 2005). Described in greater detail in the following sections, this construct builds on Shulman's (1986) pedagogical content knowledge, but includes an additional component of technology. Technological pedagogical content knowledge (TPCK) is more than just an awareness of technology, pedagogy and content; it is an awareness of the "connections, interactions, affordances and constraints" (Mishra & Koehler, 2006, p.1025) between and among the three components.

My first exposure to this construct was at the 2006 annual conference of the Association of Mathematics Teacher Educators where an entire pre-session was devoted to developing a "definition" of TPCK and a research agenda proposal for the study of TPCK. One year later, at the 2007 annual conference of the Society for Information Technology and Teacher Education, I attended a one-hour workshop that was devoted to refining this definition and further exploring the agenda for research. While TPCK is a relatively new construct, it has been accepted as a framework for research in the area of technology in teacher education (Mishra &Koehler, 2006; Thompson, 2005) and was used as the framework for my research study.

One aspect of the suggested agenda for research involves providing opportunities for "teacher candidates to develop and practice teaching lessons that take advantage of the ability of technology to enrich and enhance the learning of mathematics" (Association of Mathematics Teacher Educators [AMTE], 2006, p. 2). How to provide these opportunities is left open to the researcher. As part of the doctoral program I also began to study the Japanese approach to professional development known as “lesson study” (Stigler & Heibert, 1999). Briefly, lesson study consists of a group of educators preparing a research lesson; one member of the group then teaches this research lesson to a class while the rest of the group observes. The group then discusses the students' reactions, performance, and achievement related to the lesson, evaluating the effectiveness of the lesson as an instructional unit. Modifications are made where needed, and the lesson is taught again, generally by a different member of the group to a different group of students, and the reflective cycle repeats. Although lesson study has been used in Japan for some time, it was first introduced into a US school in 1999 (Chokshi, 2003) and has been introduced primarily as a tool for professional development with inservice teachers.

During one of my education courses I was introduced to the concept of microteaching lesson study, a form of the lesson study concept modified for use with preservice teachers. In microteaching lesson study (MLS), the preservice teachers form MLS groups and work through cycles of teaching similar to those used by the lesson study groups. The microteaching portion of MLS provides actual teaching experience as suggested by AMTE, and the lesson study portion provides opportunities for reflection on and modification of the lesson. As with lesson study, one primary focus of the MLS process is preservice teacher learning (Lewis, Perry, Hurd, & O'Connell, 2006). While MLS has been used with preservice teachers in exploring pedagogical content knowledge (M. Fernández, 2005; M. Fernández & Robinson, 2007), there is no research to date concerning the use of MLS to explore technological pedagogical content knowledge. That was the focus of my dissertation.

The two primary components of my research, technological pedagogical content knowledge and microteaching lesson study, are both relatively new topics in the area of teacher education. To my knowledge, the two have never before been combined into one research study. The goal of my project was to add to the literature base for these two constructs by exploring the use of microteaching lesson study as a teaching strategy to provide the opportunities for preservice teachers to develop technological pedagogical content knowledge.

Technology in Teacher Education

First introduced during the late 1970s and early 80s, technology training in mathematics teacher education began as computer literacy and consisted primarily of instruction in specific programming languages such as FORTRAN, BASIC or LOGO. Due to lack of hardware in the public school system, there was little transfer of this training to the classroom. In the mid 1980s, with the growth of microcomputers and related content area software, the emphasis in technology education for teachers shifted to include a specific course incorporating the use of microcomputers and content-specific technological tools. However, the focus still remained on literacy rather than instructional strategy (Glenn, 2002).

The International Society for Technology in Teacher Education worked toward changing this focus by developing a set of technology-related standards for preservice teachers to be used as a framework in teacher education programs. First developed in 1993, revised in 1997 and again in 2000, these standards encourage teacher education programs to provide preservice teachers with opportunities for authentic experiences with, and observations of, the use of technology in learning and teaching mathematics (Kelly & McAnear, 2002). Teacher education programs began to explore strategies that would provide these experiences for preservice teachers. One such strategy involved a shift from the stand-alone computer literacy course toward a more technology-rich, integrated approach, incorporating technology into all areas of the teacher education program (Hofer, 2005). Studies explored the success of this shift by examining the inclusion of technology in the preservice teachers' future classrooms and found multiple barriers still existed. These included such issues as teacher attitudes and beliefs (Christensen, 1998;

Pope, Hare, & Howard 2002; Turner & Chauvot, 1995) and teacher comfort level (Kersaint, Horton, Stohl, & Garofalo, 2003).

Technology in teacher education programs is now entering a new developmental stage. Programs are concerned not only with preservice teachers' personal use of technology but also with their development of a knowledge-base related to the use of technology as a tool in reform-oriented teaching, where the emphasis is placed on understanding concepts and applications; that is, teacher education programs are concerned with the development of technological pedagogical content knowledge. The Association of Mathematics Teacher Educators held round-table discussions at their 2006 annual conference and established a position statement that incorporates this new direction related to technology in teacher education as follows:

> With the needs of future teachers of mathematics in mind, mathematics teacher educators should provide opportunities for teacher candidates to strengthen their knowledge of how to incorporate technology to facilitate student learning of mathematics through experiences that
>
> - allow teacher candidates to explore and learn mathematics using technology in ways that build confidence and understanding of the technology and mathematics;
> - model appropriate uses of a variety of established and new applications of technology as tools to develop a deep understanding of mathematics in varied contexts;
> - help teacher candidates make informed decisions about appropriate and effective uses of technology in the teaching and learning of mathematics; and,
> - provide opportunities for teacher candidates to develop and practice teaching lessons that take advantage of the ability of technology to enrich and enhance the learning of mathematics. (AMTE, 2006, p. 2)

The question remains, how can such experiences be incorporated into teacher education programs? This research study was designed to explore the possibility of providing these experiences through microteaching lesson study.

A brief description of the two key components of this research, technological pedagogical content knowledge and microteaching lesson study, is provided here. These topics will be explored more thoroughly in the literature review.

Technological Pedagogical Content Knowledge

Technological pedagogical content knowledge (TPCK) is an expansion of pedagogical content knowledge (Shulman, 1986) which refers to the overlapping aspects of pedagogy and content. Pedagogical content knowledge focuses on the theory that to teach a specific content area the teacher must first have an understanding of the way students learn the content. Solving an equation, for example, is different than teaching students to solve an equation. The teacher must be aware of the way students perceive the topic, areas where student misconceptions occur, forms of representation that work best in reconciling these misconceptions, and multiple teaching strategies that can be used to develop a rich understanding of the topic in the prospective students (Shulman, 1986).

Technological pedagogical content knowledge adds another layer to teacher knowledge: knowledge of a technological tool. Once again, this involves more than the teacher's personal use of the tool. It is the effective use of the technology within a teaching strategy as a pedagogical tool. TPCK involves an awareness of the strategies that incorporate the use of technology to enhance student understanding of a mathematical topic and focuses on the overlapping areas of content knowledge, pedagogical knowledge, and technological knowledge. It involves a decision-making process which includes choosing the appropriate technological tool to use in presenting a specific content area. Supporting the importance of the reform mathematics emphasis, TPCK also includes decision-making related to providing opportunities for the students to use a technological tool to explore a topic in a student-centered environment. Thus TPCK involves knowledge of the interrelationships between technology, pedagogy and content.

Studies are just beginning to appear in the literature exploring the importance and development of TPCK (Keating & Evans, 2001; Margerum-Leys & Marx, 2000; Mishra & Koehler, 2006; Niess, 2005). Participants in these studies range from preservice teachers with no experience to classroom teachers with many years of experience in multiple content areas; strategies for developing TPCK range from mentoring to instructional systems design. No strategies have been explored, however, that include the use of microteaching lesson study.

Microteaching Lesson Study

The process of lesson study was first introduced to the United States through the efforts of the Lesson Study Research Group around 1989 following a comparison of variations in teaching styles used in the Japanese and American educational systems (Chokshi, 2003). The focal point of lesson study is the research lesson. Teachers work in a lesson study group to establish goals for their students' learning and then develop research lessons to achieve these goals. These goals may be specifically content-related or may be student learning oriented. A research lesson incorporating these goals is then taught in a classroom setting by one member of the lesson study group and observed by the other members. At a follow-up conference teachers examine the strengths and weaknesses of the students' experience in the lesson, and modifications to the lesson are made to enhance the learning process. A second presentation of the lesson is used to collect data concerning how these modifications benefit the learning environment.

Much of the lesson study research thus far in the United States has been related to inservice rather than preservice teachers, perhaps because the research lesson must be presented in a classroom setting before its value can be ascertained. However, one technique that would allow lesson study to be incorporated into a teacher education curriculum is the combination of lesson study with microteaching, or microteaching lesson study, a construct developed by M. Fernández (2005). This technique has been used to explore the development of pedagogical content knowledge in preservice teachers as they develop and present research lessons in a microteaching environment that actively engage their students in learning (M. Fernández, 2005). Microteaching lesson study has not been used, however, in combination with technology for the purpose of exploring the developing technological pedagogical content knowledge.

Purpose

I am the sole instructor for the technology course, Integrating Technology in the Classroom, required for the preservice teachers enrolled in our education program. With the goals of the International Society for Technology Information and Teacher Education and the Association of Mathematics Teacher Educators in mind, I have recently redesigned the course content and focus. The lesson structure has been shifted from a computer literacy approach, where emphasis was placed on learning about the technology, to a modeled approach where the emphasis is placed on learning content with technology. Much of this redesign has been the result of research projects conducted during my doctoral program. One such project used an individual case study approach to explore the use of microteaching lesson study (MLS) with the preservice teachers enrolled in my technology course (Cavin, 2006b).

As a first attempt at exploring MLS, that project was successful. I was able to explore the development of TPCK in three individual participants by applying the framework discussed in the following sections to the data collected during the MLS process. I also gained experience with research strategies, interviewing techniques, and the procedures involved in conducting MLS. Applying the experience gained though conducting these prior projects, the purpose of the current research study was to use a group case study approach to focus on the implementation of microteaching lesson study into the technology education course as a tool to investigate to the development of technological pedagogical content knowledge in preservice teachers.

Research Questions

The decisions made in relation to the use of a technological tool "will be limited not by the nature of the technology but by the decision makers' vision and expectations regarding the likely contribution of the new technology to the achievement of their educational objectives" (Kaput, 1992, p. 548). This research project will focus on these decision makers' (preservice teachers') vision and expectations as they participate in microteaching lesson study groups to address the following research questions:

1) What changes in technological pedagogical content knowledge occur as preservice teachers participate in microteaching lesson study?
2) What aspects of microteaching lesson study afford opportunities for these changes in technological pedagogical content knowledge to occur?
3) What factors and barriers influence the changes in technological pedagogical content knowledge?

Definition of Key Terms

The two key terms used in this study are both relatively new to the field of educational research. To assist the reader in identifying the focus of this study, this section contains definitions of these key terms as interpreted for use in this dissertation.

Technological Pedagogical Content Knowledge

In this dissertation, I have used two primary sources for my definition of technological pedagogical content knowledge (TPCK). The first source is the work of Mishra and Koehler (2006), where TPCK is formally introduced as a research framework using three overlapping circles representing the intersection of technological knowledge, pedagogical knowledge, and content knowledge. In applying this framework, TPCK was interpreted in my research as a preservice teacher's awareness of effective pedagogical strategies involved in the incorporation of a specific technological tool in a specific content lesson, to create a student-centered learning environment. Focused on the overlapping areas of content knowledge, pedagogical knowledge, and technological knowledge, TPCK was examined via the decisions made by the participants related to the use of a technological tool in developing, teaching, and making modifications to a technology-enhanced content lesson.

The second source for the definition of TPCK was the work of Niess (2005), which added focus to the evaluation of the development of TPCK. Niess proposed that teachers exhibit TPCK when they demonstrate an overarching concept of what it means to teach a particular subject in which technology is integrated into learning; knowledge of instructional strategies and representations for teaching specific topics with technology; knowledge of students' understandings, thinking, and learning with technology in a particular subject; and knowledge of curricula and curriculum materials that integrate technology with learning in the subject area (Niess, 2005). As the decisions of the participants related to the use of technology in their lessons were examined, these four characteristics served as a guideline for identifying TPCK.

Microteaching Lesson Study

Microteaching lesson study (MLS), as developed by M. Fernández (2005), is a process used in teacher education, in which preservice teachers work collaboratively in small groups to develop a group lesson addressing a specific goal. The group members then work through repetitive cycles involving three stages: one member of the group micro-teaches the lesson; group members watch a video tape of the lesson and evaluate the effectiveness of the lesson toward addressing the goal; and the group makes decisions to modify the lesson as needed. The cycle is repeated until all members of the group (typically three) have taught the lesson. While traditional microteaching involves a single teaching of an individually developed lesson, microteaching lessons study "engages prospective teachers in cooperative learning to develop their understanding and ability to plan, implement, and reflect on lessons" (M. Fernández, 2005, p. 38). At the conclusion of the repetitive cycles, the group prepares a final written summary of the lesson and their experiences during the MLS process.

In this research study, the MLS process was conducted with two groups, each containing three preservice teachers, and the lesson focused on the use of a technological tool in a mathematics lesson. The microteaching portion was conducted with small groups of students enrolled in a college mathematics class.

Significance of the Study

The National Council of Teachers of Mathematics (NCTM) has incorporated into its *Principles and Standards for School Mathematics* (2000) a technology principle which states, "Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning" (p. 24). Indicating multiple research studies as evidence, NCTM emphasizes that students can learn more mathematics more deeply through effective integration of technology into instruction. They admit, however, that the effective use of technology is dependent on the classroom teacher (NCTM, 2000).

Both the National Council of Teachers of Mathematics and the National Academy of Science (NAS) support a classroom environment rich in technology, with an emphasis on constructivist learning (NAS, 1996; NCTM, 2000). If we are to prepare future teachers to teach in such an environment, using technology to enhance constructivist learning, it is important that teacher education programs provide their students (preservice teachers) with exposure to technology-enhanced teaching strategies. Support for this view of technology in teacher education programs comes from several areas. Organizations such as National Council for Accreditation of Teacher Education (NCATE), and the International Society for Technology in Education (ISTE) have adopted standards related to the inclusion of technology education in teacher education programs. They suggest that "teacher preparation programs must provide prospective teachers opportunities to learn important skills and examine pedagogical issues for using technology in the classroom" (Kersaint et al., 2003, p. 549).

Content-related organizations such as the Association of Mathematics Teacher Educators (AMTE) have followed up the suggested national standards with specific research agendas. The Technology Committee of AMTE has, for example, developed a research agenda organized around the ISTE standards that states, "Mathematics teacher preparation programs must ensure that all mathematics teachers and teacher candidates have opportunities to acquire the knowledge and experiences needed to incorporate technology within the context of teaching and learning mathematics" (Niess, 2006, p. 201)

In considering the opportunities that would provide experiences for preservice teachers to acquire technological pedagogical content knowledge, the issue of what it means to "acquire knowledge" should be addressed. As stated above, both NCTM and NAS emphasize constructivist learning. From a constructivist perspective, "knowledge is not passively received, but is actively built up by the cognizing subject" (Wheatly, 1991, p 10) and is developed through actions and experiences. What a person "knows" is a product of his experiences. Rather than viewing knowledge as a body of facts with known truths to be disseminated by the teacher, the constructivist views knowledge as a process of understanding that occurs in a learner within a context (Wheatley, 1991). With the emphasis on context, the process of learning mathematics and science shifts from identifying a set of skills, to "establishing learning environments conducive to children constructing their mathematics and science in social settings" (Wheatley, 1991, p 12).

If context and constructivist learning are important in learning mathematics and science, they should also be important in learning how to teach mathematics and science. When teacher education programs are considering strategies that will provide opportunities for preservice teachers to develop technological pedagogical content knowledge, the process of constructing knowledge by developing schemes through actions and experiences should be considered. The microteaching lesson study process is one strategy with the potential to, paraphrasing Wheatley, establish a learning environment conducive to preservice teachers constructing their technological pedagogical content knowledge in social settings. By incorporating microteaching lesson study into my technology teacher education course, my intent was to offer a context with the potential to provide the prospective teachers with opportunities to construct their own technological pedagogical content knowledge.

Because technological pedagogical content knowledge and microteaching lesson study are both relatively new concepts in the field of educational research, the research-based body of knowledge in both areas is limited. It is my hope that the process of conducting the research and reporting the findings has made a significant contribution to the literature base in these two areas.

CHAPTER 2
LITERATURE REVIEW

The two primary components of the research questions are technological pedagogical content knowledge (TPCK) and microteaching lesson study (MLS). These two topics will constitute the majority of the literature review. A preliminary review of pedagogical content knowledge and technology in mathematics education will be addressed first to set the stage for the discussion of technological pedagogical content knowledge and microteaching lesson study.

Pedagogical Content Knowledge

Content knowledge refers to an understanding of the subject matter relating both to what is so and why it is so, and pedagogical knowledge relates to teaching strategies that are applicable across all content areas. A recent focus in educational research has been on the overlap of these two areas, which has become known as pedagogical content knowledge (Shulman, 1986). It is not enough for preservice teachers to know their subject matter, or to know commonly used teaching strategies. They must also know how to apply those strategies to their specific content area. Defined by Shulman (1986) in his presidential address to the annual meeting of the American Educational Research Association,

> Pedagogical content knowledge goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching . . . . Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the way of representing and formulating the subject that make it comprehensible to others. (Shulman, 1986, p. 9)

While conducting research for her doctoral dissertation under the supervision of Shulman on the development of PCK in English teachers, Grossman (1988) identified four key components of PCK. The first is an overarching concept of teaching a subject. This includes both knowledge of and beliefs about the purposes for teaching a particular subject at a particular level and is reflected in the teachers goals. A second component is knowledge of students' understanding and potential misunderstandings. Teachers should have an idea of what students already know about a subject as well as common misunderstandings that occur. The third component relates to knowledge of curriculum in both the vertical and horizontal avenues as well as an awareness of available curricular materials. The final component relates to knowledge of instructional strategies and representations. The teacher needs a repertoire of possible strategies from which to select in any given situation (Grossman, 1988; Grossman, 1989).

Grossman's four components of pedagogical content knowledge have been used as a framework for the analysis of a teacher's knowledge as demonstrated in the presentation of a particular lesson (Borko, 1991). Characteristics of the lesson as well as the interactions of teacher and student were tied back to Grossman's components in determining the quality of pedagogical content knowledge demonstrated. This same technique proved useful in data analysis for this research project.

Technology in Mathematics Education

Technology is changing the world in which we live, and education is no exception. The rate of technological change in public schools and schools of education, however, is lagging. As one scholar explains, "finding aspects of education not deeply affected by the computational medium is not an easy matter, unless, of course, one looks in schools, or in US schools of education" (Kaput, 1998, p. 1).

Computers and technological tools have been integrated into the classrooms since the early 1980s (Kaput, 1992; Kelly, 2003). Use of computers for drill and practice and calculators for simplifying computations is well-documented, but research related to the use of technology in a student-centered environment as a tool for enhancing the construction of mathematical knowledge is still new. The exploratory nature of technology provides students an opportunity to analyze data, make conjectures, test their hypotheses, and investigate algorithms, allowing students to construct knowledge: to take full advantage of the capabilities of the technology, we need to "identify what is different about the new electronic media and what those differences mean in terms of cognition, learning, teaching and related matters" (Kaput, 1992, p. 516).

For preservice teachers to effectively incorporate the use of technological tools requires an awareness of these "related matters" (Kaput, 1992, p. 516). However, just because preservice teachers are aware of the possibilities does not mean they will take advantage of them.

Preservice teachers need to be provided opportunities for practice (Olive & Leatham, 2000). Kaput (1992) suggested that the use of technology (computers) in direct support of instruction requires the integration of three bodies of knowledge and/or hypotheses about that knowledge: a theory of the subject matter, general knowledge of students' form of learning and interaction with the subject matter, and particular knowledge of the individual learner at each state in the interaction with the technology. This analysis bears a strong resemblance to the concept of technological pedagogical content knowledge as described below.

Technological Pedagogical Content Knowledge

TPCK Definition

Central to my research study is the concept of technological pedagogical content knowledge (TPCK). TPCK is the link between the use of technology as a performance tool and the use of technology within a teaching strategy as a pedagogical tool. The skills involved in learning mathematics with technology are different from those in learning to teach mathematics with technology (Niess, 2005). TPCK involves an awareness of the strategies that incorporate the use of technology to create a student-centered learning environment, and is focused in the overlapping areas of content knowledge, pedagogical knowledge, and technology (Mishra & Koehler, 2006).

The rapidly-changing hardware associated with technological instructional tools makes it difficult to determine appropriate teaching experiences that should be included in teacher education programs in order to develop TPCK. Simply providing future teachers an opportunity to use specific technologies in specific situations is not enough. They run the risk of their lessons being outdated before they graduate from their teacher education program.

Teacher educators should include experiences that develop decision-making skills concerning the incorporation of technology into mathematics instruction, focusing on the methods preservice teachers use to make their decisions rather than the technology itself. TPCK is not limited to specific technologies or content. Rather, it focuses on the process by which teachers make a decision relating to a technological tool and its pedagogical benefit to a particular lesson on a particular topic. To effectively make such decisions requires an understanding of the interaction of the three components of TPCK: the technology itself, the pedagogy related to teaching a specific content, and the content itself.

To identify the development of TPCK in preservice teachers will require a working definition for TPCK related skills. For this purpose, Niess (2005) added technology to the components of pedagogical content knowledge identified by Grossman (1988, 1989). Paraphrasing Niess' definition, teachers exhibit TPCK when they demonstrate each of the following components:

- an overarching concept of what it means to teach a particular subject in which technology is integrated into learning;
- knowledge of instructional strategies and representations for teaching specific topics with technology;
- knowledge of students' understandings, thinking, and learning with technology in a particular subject;
- knowledge of curricula and curriculum materials that integrate technology with learning in the subject area. (Niess, 2005, p. 511)

Niess applied her definition of TPCK in her work with inservice teachers. A summary of her work along with related findings is provided in a later section.

In conducting their studies related to professional development of inservice teachers through their Design-Based Research Collective, Mishra and Koehler have developed a framework for technological pedagogical content knowledge (Koehler & Mishra, 2005; Mishra & Koehler, 2006). In this framework, they have made an effort to capture the essential qualities of teacher knowledge that are necessary in integrating technology into teaching, while also addressing the complex "situated nature" of this knowledge. They state that for a teacher to incorporate technology in a thoughtful, pedagogically appropriate manner requires the development of TPCK (Mishra & Koehler, 2006). Mishra and Koehler have represented TPCK through the use of a Venn diagram (Figure 2.1), where the individual circles represent the knowledge components of content (C), pedagogy (P), and technology (T) and the overlapping area of all three circles represents TPCK.

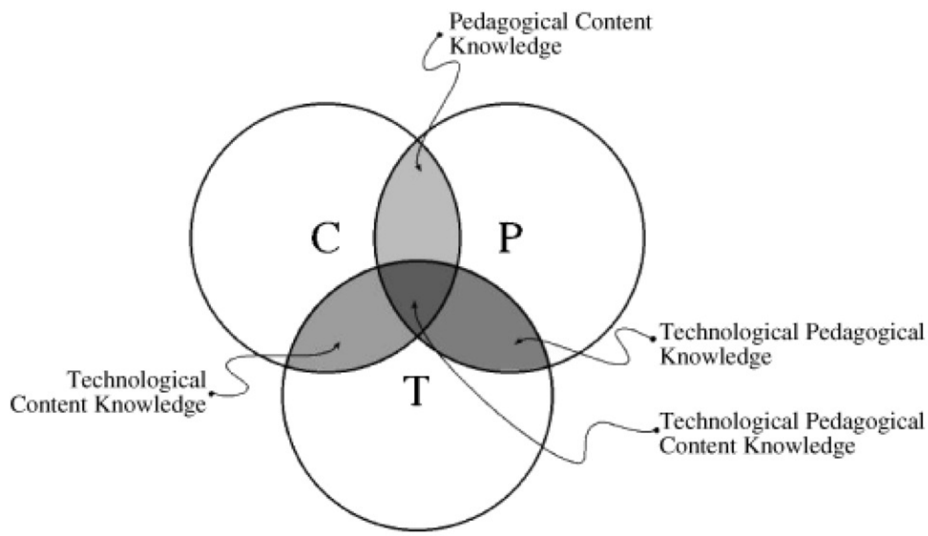


Figure 2.1 Diagram representing the overlapping components of technological pedagogical content knowledge (Mishra & Koehler, 2006, p. 1025).

Content knowledge, perhaps the easiest to define, is subject-area knowledge. In mathematics this includes knowledge of such things as formulas, algorithms, postulates and theorems as well as the procedures involved in their application, such as problem solving and reasoning. Pedagogical knowledge is generic in nature – that is, not related to the specific subject matter at hand. It deals with such things as classroom management, lesson plan development, knowledge of student learning and methods of assessment. Pedagogical knowledge is not "what" is taught but "how" it is taught. Technological knowledge is focused on hardware and software. This might include but is not limited to access to the Internet, the use of computer software including word processing, spreadsheets, or content related software (Geometer's Sketchpad, TI-Interactive, TI-SmartView), graphing calculators, calculator-based rangers (CBRs), and audio and video recordings, among others. Preservice teachers should be aware of what forms of technology are available as well as the mechanics involved in using what is available.

The relationship between each pair of concepts is then identified as pedagogical content knowledge (PCK), technological content knowledge (TCK), and technological pedagogical knowledge (TPK). Emphasis is placed on the "connections, interactions, affordances, and constraints" (Mishra & Koehler, 2006, p. 1025) between and among the three components. The intersection of the three component circles represents technological pedagogical content knowledge (TPCK). More than just the sum of technology, pedagogy, and content, the significance of the overlapping areas lies in the interaction between the three components, described by Mishra and Koehler as follows:

> TPCK is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face; knowledge of students' prior knowledge and theories of epistemology; and knowledge of how technologies can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones. (Mishra & Koehler, 2006, p. 1029)

TPCK Related Research

While the research of both Niess (2005) and Mishra and Koehler (2006) focused on the development of TPCK, the research designs were quite different. Participants in the Niess (2005) study were graduate students enrolled in a one-year program to prepare science and mathematics teachers to integrate technology. All 22 participants held at least a bachelor's degree in their field, thus coursework in the program focused primarily on instructional strategies and general education requirements. The program was designed to include a specific technology component in each of the four academic terms (using the quarter system, and including one summer term). Rather than simply introducing technological tools, the emphasis was placed on using technological tools in a content lesson. The technology components in the program were taught by subject-specific technology educators, and one classroom component contained a requirement for the participants to micro-teach a technologically enhanced lesson. Field experiences were included every term, with a twelve-week, full-time teaching practicum during the winter quarter. During the practicum, the participants were expected to incorporate technology into their lessons and were required to reflect upon their experiences. Reflections contained an analysis of students' understanding of the content, success of the technology integration, and the teaching of the lesson with technology.

Niess (2005) collected data qualitatively from five case studies and coded using the four components of TPCK adapted from Grossman's (1988, 1989) pedagogical content knowledge definition. Results indicated various levels of success with developing TPCK. Using pseudonyms, Denise had a vision of technology as a tool, but felt that teaching the use of the technology was outside her job description, demonstrating the importance of participant beliefs in the development of TPCK. Marissa, however, with the help of her classroom supervising teacher, planned a unit involving Calculator Based Labs (CBLs) so that her students could get a "clearer understanding" of the subject matter. Terry also used the CBLs in a science experiment and felt that "an integration of technology in the strategies motivated students as well as enhanced their learning" while Karen felt that technology was "frivolous." But perhaps the most accepting of technology into her instructional strategies was Dianne who stated, "I will not refuse a new technology because it appears too difficult to learn. I will only refuse a new technology if it does not relate to mathematics." She felt that "technology was integral to mathematics and thus to learning mathematics" and, by the end of student-teaching, she was able to engage her students as active learners of mathematics (Niess, 2005, pp. 515-519).

In a follow-up study, Suharwoto and Lee (2005) conducted a qualitatively based investigation of the role played by various aspects of that same teacher education program on the development of the individual components of TPCK in a cohort of eight graduate students preparing to teach mathematics. The six aspects of the program examined were coursework, microteaching, e-portfolios, faculty or course instructor, university supervisor, and cooperating teacher. Data sources included coursework documents, questionnaires, interviews, and observations. Data analysis was conducted to identify the impact of each component of the program on the development of technology, content, and pedagogy.

Results indicated that in the combined areas of technology, pedagogy, and content, students perceived the coursework to be the most influential aspect of the program, followed by the influence of university faculty. E-portfolios, micro-teaching and university supervisors were found to have a strong influence on pedagogy, while the cooperating teacher influenced pedagogy and content. The cooperating teacher's lack of influence on the technology area clearly shows the importance of incorporating technology into preservice training. If the training is not a part of the preservice teacher's educational process, he or she may not have an opportunity to develop these skills later.

In contrast to the studies concerning preservice teachers described above, studies conducted by Mishra and Koehler (e.g., Koehler & Mishra, 2005; Mishra & Koehler, 2006) were primarily in the area of faculty development for inservice teachers. In various studies conducted with several cohorts over a five-year period, participants began with a personal instructional goal and were assisted in selecting a technological tool to accomplish that goal. The participants were then introduced to that particular technological tool, creating a need for the tool before providing instruction in the use of the tool. Because several research studies were conducted, the participant list was quite varied and included college faculty and graduate students from various schools in multiple content areas, all with the common purpose of using technology in designing an instructional lesson or course.

Both quantitative and qualitative data were collected; quantitatively through surveys used to identify participants' perceptions of their expertise in the areas of content, pedagogy, technology and the overlapping areas (Koehler & Mishra, 2005) and qualitatively through case studies of learning-by-design groups (Koehler, Mishra, Hershey, & Peruski, 2004). Both quantitative and qualitative data were analyzed using the T-P-C framework. The survey instrument contained specific questions related to each of the individual areas as well as their overlaps. Qualitatively collected data (observations and interviews) were initially coded into the three basic categories: content, pedagogy and technology. These categories were not, however, mutually exclusive. Many items were coded in multiple categories: pedagogy and content, technology and pedagogy, technology and content, or most importantly, technology, pedagogy, and content, representing technological pedagogical content knowledge (TPCK).

It is important to emphasize that TPCK is more than just the combination of the three independent concepts of technology, pedagogy and content. It represents a specific knowledge of how these three basic concepts interact. Results from the learning-by-design research studies indicated that when the participants "designed" their own product (web site, lesson, etc.) they "[were] confronted with building a technological artifact while being sensitive to the particular requirements of the subject matter to be taught, the instructional goals to be achieved, and what [was] possible with the technology" (Koehler & Mishra, 2005, p. 148), indicating an awareness of the overlapping areas of technology, pedagogy and content. "The introduction of technology [into the design] causes the representation of new concepts and requires developing a sensitivity to the dynamic, transactional relationship between all three components suggested by the TPCK framework" (Koehler & Mishra, 2005, p. 134).

Of particular interest to my research is the in-depth analysis of a specific case study in the learning-by-design projects, that of Dr. Shaker (Koehler et al., 2004). Dr. Shaker was a participant in a project which paired graduate students from various backgrounds with a specific faculty member for the purpose of developing an on-line course. The faculty member (Dr. Shaker) identified the desired course content while the graduate students provided technological support as well as pedagogical strategies associated with on-line learning. Their first hurdle was to establish a cohesive working relationship. Each group member was experienced in their respective area, but not experienced in working in a group with such a common goal, which lead to uncertainty as to what role each individual should play in the production of course. Initial efforts yielded progress in the areas of content from Dr. Shaker, technology from the web designer, and pedagogy from the instructional systems designer, but little interplay between the three areas.

As the group continued to work, however, they began to develop an understanding of the interrelationship of the three components. While each member possessed expertise in their respective area, they began to realize the importance of communicating both their goals and their constraints to the other members of the group. For example, an initial web design was evaluated from a pedagogical standpoint and revised. Content was added in the form of documents, reading assignments, and internet links. Technology was used to coordinate the content with the desired pedagogical approach in an effort to create an "online learning community" (Koehler et al., 2004, p. 44).

The group found the interactions between technology, pedagogy and content "had an impact on the representation of the content in an online environment" (Koehler et al., 2004, p. 44). In working together as part of this project the group realized that "the technology was not general purpose or neutral, but rather, aspects of course content and the way Dr. Shaker wanted to teach was intricately connected to what technology they used and how they would use it" (Koehler et al., 2004, p. 46). While the content for Dr. Shaker's course was not mathematics, the cooperative group approach to the design of the lesson and the explorations in the development of TPCK as the participants interacted within this group, correlates with my research focus.

A quantitative analysis of TPCK was also conducted by Mishra and Koehler (2005) using the learning-by-design technique with four faculty members and 13 students. Survey data collected several times during the semester were analyzed for shifts in response patterns. Using a 7-point Likert Scale with 1 = strongly agree and 7 = strongly disagree, participants responded to questions in two primary areas. The first was related to the overall group functions, such as "our group is getting a lot of work done" and "everyone in our group is making a significant contribution" (Koehler & Mishra, 2005, p. 141). The second group of responses was related to technology, pedagogy, content, and all overlapping areas, such as "our group has had to modify course content in order to adapt it to our online course" and "our group has chosen technologies to fit our course content and the faculty member's teaching philosophy" (Koehler & Mishra, 2005, p. 147). Responses to both categories indicate a significant shift from "disagree" toward "agree" as the semester progressed, offering quantitative data in support of the development of TPCK among the participants.

Other investigations into the concept of technological pedagogical content knowledge include the work of Keating and Evans (2001). Their study focused on the relationship between the comfort level of “technology-savvy” students entering the education program and their future inclusion of the computer in the classroom for instructional purposes (Keating & Evans, 2001, p. 160). Their concept of TPCK involved the teacher making "judicious" decisions related to the inclusion of new technologies that allow the subject matter to be represented in the most appropriate ways. A teacher that has developed TPCK "understands the effect technology may have on her student’s conceptions of the subject, the extent to which student’s use of technology may actually impede understanding of a subject, and the inevitable challenges that accompany any new technology" (Keating & Evans, 2001, p. 161).

Eleven preservice teachers enrolled in Transforming Classrooms with Technology participated in the Keating and Evans study, and qualitative data were collected via interviews. While the participants in this study were considered to be computer literate (comfortable with using the computer for personal use) they were not comfortable with incorporating the computer into their instruction. Keating and Evans (2001) identified the problem as a lack of TPCK. Three areas surfaced that negatively affected the preservice teachers’ confidence in the use of technology in the classroom: the use of computers (or lack of) by their instructors during their coursework (referred to as modeling), individual usage of computers prior to entering the program, and the vision held by the preservice teacher of the use of computers in his or her classroom (termed as pedagogical fit).

The conclusion reached was that, to improve the development of TPCK, "preservice teachers need to be engaged in thinking about how technology can be integrated into various learning strategies" (Keating & Evans, 2001, p. 163). The researchers emphasized that teacher education programs offer multiple strategies for teaching mathematical concepts, but often present a single strategy for the incorporation of technology, and they suggested that teacher education programs begin to develop innovative ways to involve preservice teachers in developing TPCK.

Focusing on yet another aspect of the development of TPCK, Margerum-Leys and Marx (1999) examined preservice teachers' beliefs. These researchers followed nine preservice English teachers through a year-long, field-based course where the participants were involved in "shadowing teachers and students, teaching, observing a variety of teachers, visiting schools, and generally getting a feel for the rhythm of the public school" (Margerum-Leys & Marx, 1999, p. 14). The preservice teachers spent two days each week in the field and the other three days completing the remainder of their coursework on the university campus. Data were collected through two structured interview sessions. Both interviews focused on participants' backgrounds and beliefs, with an additional focus in the second interview on acquired technology skills. Data were then transcribed and coded using NUDIST. Hoping to portray the participants' beliefs in their own voices, transcripts of the interviews were returned to the participants with a request for verification of accuracy, with an additional request that statements deemed important by the participant be highlighted and comments made in the margin reflecting why they were considered important. This gave an opportunity for the preservice teachers to expand on comments made during the interview sessions.

This project was not designed to have an effect on or to change preservice teacher beliefs, but rather to explore possible themes. During the analysis, the following themes related to beliefs toward the use of technology emerged: social dynamics, used by teachers, curriculum, used by students, learning, knowledge and availability. Of these the greatest percentages of responses by participants were in the areas of used by students, learning, knowledge, and availability. Themes were re-examined across cases with several interesting conclusions. First, the findings supported the need for preservice teachers to feel comfortable with incorporating technology into the classroom. Most of the participants felt comfortable using technology as a teacher tool (e.g., word processing and electronic grade books), but were not comfortable using computer-based technology in classroom instruction. A second finding indicated that the participants felt their computer skills grew more by using computers for exploration and authentic tasks than by formal educational experiences. This emphasizes the need to actively engage preservice teachers in learning during their technology-related instructional coursework.

Additional research studies conducted by Margerum-Leys and Marx (2000, 2002) focused on the development of TPCK through the interaction of preservice-teacher and mentor-teacher pairs. Three pairs of teachers (six teachers in all) participated in the study, two pairs teaching in middle school science and one pair in middle school language arts. The preservice teachers were enrolled in university courses during this experience; however, the primary focus during the Fall term was the field experience. Data sources included observation records maintained in a journal and transcriptions of three interview sessions conducted for each teacher pair. The data were examined for any instances in which "the teachers were using or guiding the use of educational technology for teaching and learning purposes" (Margerum-Leys & Marx, 2002, p. 436). When such instances were identified, they were coded as related to content knowledge, pedagogical knowledge, or pedagogical content knowledge – each category inherently including the use of educational technology. Focusing on the generic use of educational technology, examples of coding in each knowledge category contained the following: content knowledge was coded when participants demonstrated knowledge of hardware capabilities, likely equipment failures, general structures of web sites, and similar hardware and software knowledge; pedagogical knowledge was coded, for example, when participants demonstrated knowledge of time management, motivating students, adjusting instruction to meet special needs, and assessment of student work; and pedagogical content knowledge related to educational technology focused on participants' knowledge of common mistakes made by students and how to help them correct the mistakes, when to explain a procedure, model the procedure, or do the procedure for the student, and matching the sequencing of an instructional technology activity with appropriate sequencing for students given curricular goals, time constraints, and particular abilities of individual and groups of students (Margeurm-Leys & Marx, 2002, p. 454-456).

Findings indicated that 8% of the data were coded as pedagogical content knowledge of educational technology (TPCK). Several specific examples were provided where both the mentor-teacher and student-teacher were observed demonstrating pedagogical content knowledge of educational technology, interestingly flowing in both directions: from mentor to student, and from student to mentor. Margerum-Leys and Marx pointed out the importance of authentic experiences for the student-teachers, and argued that "opportunities for authentic experiences are a necessary condition for learning to occur" (Margerum-Leys & Marx, 2002, p. 458). This concept of authentic experience is one key component of microteaching lesson study as used in my research.

Turner and Chauvot (1995) also studied the beliefs of preservice teachers through the case studies of Liz and Christine (pseudonyms), two student interns, and focused on the effects of their beliefs as barriers to technology incorporation into teaching strategies. Results of interviews and observations during the internship indicated that these preservice teachers held a central, primary belief that their own success with technology resulted from the fact that they already knew the mathematics involved. This belief was emphasized when one of the preservice teachers indicated that technology should be used in upper level classes only, since those students are already familiar with the mathematical concepts. The two preservice teachers also agreed that their primary belief was in the use of mathematics, and the use of technology was a secondary belief. This was emphasized when they insisted on making calculations first by hand, and only using the calculator when needed as a computational aide.

There were differences, however, in the belief structures of the two participants. While neither one incorporated the use of technology into her lesson, the interfering belief structure varied. For Christine, one central, primary belief was that she wanted to reach every student, which often meant using alternative strategies. She considered technology to be one of these alternative strategies, but more often opted to use something else (peer teaching, manipulatives, etc.). Liz, on the other hand, held the central belief that the role of the teacher was that of an authority figure. Her teaching was teacher-centered, and the use of technology often created a more student-centered environment, in contradiction with her belief. The work of Turner and Chauvot (1995) supports the theory that conflicts in beliefs often inhibit the inclusion of technology into the classroom. Teacher education programs must, therefore, strive to shift these beliefs toward the inclusion of technology as a primary pedagogical tool.

A second participant-related factor influencing the incorporation of technology is the comfort level of the teacher. Survey results indicate that while middle and high school mathematics teachers view such technologies as graphing calculators, dynamic geometry software, computer algebraic systems, and data collectors to be of high importance, their comfort level with these technologies is low, yet the correlation between comfort level and integration into the classroom is high (Kersaint et al., 2003). Through engaging preservice teachers in learning with technology, their comfort level with technology in a classroom setting should increase.

One aspect still to be explored was a technique for recognizing the development of TPCK. One possibility was introduced by Woodbridge (2004) in a study of 16 inservice teachers in a variety of academic areas across all grade levels. Participants in the study were graduates of a Masters of Arts in Teaching program that contained a component related to teaching with technology. Classroom observations were conducted using the ISTE National Educational Technology Standards for both students and teachers as a guide. During the observations, as students participated in technologically-enhanced lessons, Woodbridge recorded observed behavior related to the various student standards. For example, 14 students were observed "[using] technology tools to process data and report results" (p. 8). Teacher behavior was also categorized, using the four components of the ISTE teacher standard related to teaching, learning and the curriculum. Thirteen teachers were observed, for example, to "facilitate technology enhanced experiences that address content standards and student technology standards" (p. 10). This technique of recording observable characteristics in relation to nationally established standards was expanded for my research study to include standards in the additional areas of pedagogy and content, and was used in the development of my initial coding scheme.

Microteaching Lesson Study

Introduction

During the early portion of my teaching career I worked with another mathematics teacher who was very interested in cooperative planning. We taught many of the same classes, had many of the same teaching philosophies, and our strengths and weaknesses complimented each other. As a result, we spent a great deal of time planning lessons together and, most importantly, reflecting on the lessons and recording recommended changes for future teaching. While we did not begin with the key component of lesson study, a research lesson, we did in many ways participate in a mini-lesson study group. When I changed schools, no one in the new department was interested in pursuing this concept. I missed it, and it was not until I read about the concept of lesson study in “Teaching is a Cultural Activity” (Stigler & Hiebert, 1999) that I realized the potential impact of what we had begun, and why I missed it so much. I immediately began to consider incorporating lesson study opportunities for the preservice teachers into our program. As I read additional assignments for my doctoral level classes, I began to realize the importance of such issues as engaging students in learning, providing opportunities for students to construct learning, and classroom discourse, which are all components of the lesson study process.

The difficulty, of course, is that lesson study (described in more detail below) involves the repetitive cycle of cooperatively developing a research lesson, teaching the lesson, and then reflecting on the effectiveness of the lesson. Incorporating lesson study into the teacher education program required an opportunity to teach. Microteaching lesson study (M. Fernández, 2005) afforded the solution. The combination of microteaching and lesson study, or microteaching lesson study, combined the cooperative development of a learner-centered lesson with an opportunity to teach that lesson in a classroom setting.

To introduce microteaching lesson study I first provide a description of lesson study as introduced by Stigler and Hiebert (1999) followed by summaries of articles based upon the experiences of lesson study researchers. This is followed by a description of microteaching lesson study research (M. Fernández, 2005; M. Fernández & Robinson, 2007). Microteaching lesson study was a key component in the methodology used in my research.

Lesson Study Overview

Initial interest in lesson study arose in the United States following an examination of videotaped samples from the Third International Mathematics and Science Study (TIMSS), conducted in 1995, in which students from Japan significantly outscored students from the United States. The analysis of the samples identified one key difference between American and Japanese educators – the Japanese practice of lesson study (Stigler & Heibert, 1997). As it was believed to be at least partially responsible for the discrepancy in scores, interest in lesson study grew. Others (e. g., C. Fernandez & Yoshida, 2000; Lewis & Tsuchida, 1998) began to investigate the Japanese concept of lesson study, and questions arose as to whether such a technique could be used successfully in the United States.

If we compare the typical activities of American and Japanese mathematics classrooms, we find multiple differences in their scripts. In the United States the script is focused primarily on a set of procedures. It is skill oriented and teacher directed, and mathematical material is presented piece by piece. The teacher provides the materials necessary to solve a problem, paced to allow coverage of the required curriculum. In contrast, the Japanese script includes a study of relationships between concepts, facts, and procedures, and is very student-centered. It is presented in relation to the solution of a given problem, but the students' attempts at solving the problem are recorded and presented for discussion (Stigler & Hiebert, 1999).

Known as a "research lesson" in Japan, lessons are developed as the product of a group effort. Teachers meet to set goals for the classroom and then develop lessons to accomplish these goals in contrast to the traditional American lesson which contains only a few objectives and is prepared by a single teacher. Once prepared, the Japanese research lesson is taught by one member of a group of teachers while the others observe. Time is spent discussing the outcomes of the lesson, making modifications to the design, and then teaching the lesson again in a different setting by another member of the lesson study group. A final evaluation of the lesson is conducted, and a written report is generated to be shared with other educators.

During their discussions of the research lesson, Japanese educators discussed such issues as the students' responses, the organization of the chalkboard space, how time management and individual student differences were handled, and how the ending of the lesson was structured. The process of working in lesson study groups has created an atmosphere where Japanese teachers work collaboratively, becoming professional educators. Efforts to translate this technique into an American version have grown steadily (Chokshi, 2003). The following sections describe research projects that focus on incorporating lesson study into the United States.

Lesson Study Research

Initial research related to Lesson Study emanated from two primary sources: the research team of Stigler, which included Clea Fernandez, Yoshida, and others, and the research team of Lewis. The primary focus of both teams has been in the area of professional development.

The Stigler team. The first two research studies conducted by the Stigler team were designed to identify features of lesson study that can inform our understanding about how to structure teacher learning and the challenges that US schools are likely to face when engaged in lesson study. The first was conducted by C. Fernandez and Yoshida (2000). They investigated the use of lesson study with a group of 14 teachers in a K-8 New Jersey urban setting who were mentored by Japanese teachers from a nearby school in Connecticut. Beginning in September of 1999, these teachers met once a week through fall and winter. The overarching goal established for their lesson-study team was to foster problem solving abilities and responsibility for learning in their students. The first set of lessons was taught in late January and re-taught in late February while the second set was taught in April and May. Findings indicate a portion of the script that varies between the U.S. and Japan is that the U.S. teachers' instincts while observing the lesson were to help the teacher in the classroom, offering "another set of hands." This is counter to the Japanese concept of un-intrusive observing where the idea is that the observers be "another set of eyes" (C. Fernandez & Yoshida, 2000, p. 36).

The second study was conducted with a group of teachers from New York (C. Fernandez, 2002). These teachers had recently undergone a curriculum alignment that included the adoption of standards-based curricula. The overarching goal they established was fostering the development of critical thinking skills and encouraging students to ask rich, thoughtful questions. To implement this goal the team settled upon the use of visuals and observing how visuals developed questioning skills in the students. Ongoing analysis of these two groups has contributed to the research base, primarily in the area of barriers to the use of lesson study in the United States.

One common barrier seen among the two studies was that both groups of US teachers were found to be hesitant to open their classrooms to their peers or to provide feedback in a constructive way. They also found it difficult to allocate time to participate in lesson study (C. Fernandez & Yoshida, 2000; C. Fernandez, 2002). Another significant barrier was the lack of research skills in US teachers. Since the heart of lesson study is the research lesson, which is based on goals established through data analysis, this weakness slows the developmental process from the start. Without research skills to collect and analyze data, it is difficult to identify goals as well as determine appropriate content to be included in order to enhance achievement of these goals. Because the analysis of the lesson itself is based on data collected during the presentation of the lesson, these weak research skills can inhibit that process as well. The final phase of lesson study, involving writing the report and generalizing the study to other classrooms was also difficult for the US educators. (C. Fernandez, 2002; C. Fernandez, Cannon, & Chokshi, 2003)

Other common barriers were related to misconceptions about lesson study. These include the misconception that lesson study is focused on creating and perfecting a unique, original, never-seen-before lesson. To the contrary, no lesson is ever perfect, and conducting lesson study on traditional lessons can offer as much benefit as developing new ones. The misconceptions that lesson study is designed to create a library shelf full of perfect lessons and that there is no benefit in conducting just one lesson study were also identified. Neither perception is valid. Even a single lesson study can provide benefit to both students and teachers, and, while the sharing of lessons is recommended, it is not suggested that lessons created by one lesson study group be accepted "off the shelf" by another (Chokshi & C. Fernandez, 2004).

While it may appear that lesson study faced overwhelming barriers in the US system, the studies also led to suggestions for overcoming some of these barriers. Outside assistance may be required for US teachers to move toward a more reform-oriented teaching style by engaging students in research lessons. One option for outside assistance is a lesson study coach. This coach is envisioned as an assistant to the team, providing help in such areas as the use of technology, pedagogical strategies, content exploration, and research skills development (C. Fernandez et al., 2003). This assistance was provided by the Japanese teachers in the New Jersey cohort, but could be provided by a university coordinator, or in the case of my research study, the course instructor.

The Lewis team. In the first published scholarly article related to lesson study, Lewis and Tsuchida (1998) provided a set of characteristics for various types of research lessons and described the rippling effect created by the implementation of research lessons. Based on her observations in Japanese schools, Lewis described lesson study as a research cycle of studying curriculum to formulate goals, planning, conducting research (via teaching and observing), reflecting, and then starting the cycle again adapting curriculum and formulating goals based on the research results. However, she admits that, while interest in the lesson study process is multiplying, and the incorporation of a single lesson study development is wide spread, the completion of this cycle from goal setting back to goal setting in actual lesson study groups is very limited (Lewis, Perry, & Murata, 2006).

One exception to this limitation is the incorporation of the lesson study approach in the professional development program at Highlands Elementary School in California (Lewis, Perry, Hurd et al., 2006). Beginning in 2000, and now in its sixth year, the program was established when two of the authors, Hurd and O'Connell, began looking for a professional development model that would encourage teacher-led improvement of classroom instruction (Lewis, Perry, Hurd et al., 2006). In the first year a group of four Highlands teachers conducted two lesson study cycles and presented the results at a faculty meeting. Their presentation was well received, and nearly all the faculty at Highlands began participating in lesson study cycles. A comparison of school, district, and state mean scale scores for grades 2 to 5 from 2002 through 2005 show the school scored higher than district or state average for the entire four year period. The success of the Highlands program has been attributed to the faculty's ability to look past the surface features of lesson study, such as the development of lesson plans, to the underlying principles: Lesson study is about teacher learning, not just about lessons; effective lesson study hinges on skillful observation and subsequent discussion; lesson study is enhanced by turning to outside sources of knowledge; finally, the phases of the lesson study cycle are balanced and integrated (Lewis, Perry, Hurd et al., 2006).

To help identify characteristics of effective programs and provide guidelines for the implementation of new programs, a research agenda is needed that expands the descriptive knowledge base on Japanese and U.S. lesson study, polishes the mechanism used to conduct lesson study, and tests design-based research cycles. There are, however, concerns related to the implementation of this research agenda (Lewis, Perry & Murata, 2006). It is important that evaluations of lesson study projects be conducted at a "local" level and that summative evaluations are not applied too soon. Lesson study does not lend itself to cause and effect studies. To make the statement that "lesson study works" may not be appropriate. Lesson study should be judged, instead, on the instructional improvements that may be the result of conducting it. It is also important that lesson study be defined productively to fit the specific needs of the project at hand. If the design does not work, refinement should be encouraged, and lesson study designers should make efforts to cross the boundaries set by content areas, institutions, or outcomes of prior studies (Lewis, Perry, & Murata, 2006). Lewis (2002) combined these suggestions for designing lesson study into *A Handbook of Teacher-Led Instructional Change* that served as a guide for the development of the lesson study portion of my research design.

Microteaching Lesson Study

The process of microteaching, when used in a teacher education program, typically involves the preservice teacher developing a lesson plan, and then teaching that lesson to a small group of his or her peers, or in some cases a small group of classroom students. The lesson is often videotaped. The preservice teacher then reviews the tape and reflects primarily on the strengths and weaknesses of the presentation of the content and the pedagogical style. Microteaching has been shown to be an effective strategy in strengthening pedagogical skills (Metcalf, Hammer, &

Kahlich, 1996), but lacks the repetitive reflective process involved in the lesson study process described above. Microteaching lesson study offers an extension to microteaching that incorporates the repetitive reflective cycle important in the lesson study process. Microteaching lesson study (MLS) is designed to be a collaborative experience that will allow prospective teachers to engage not only in the development of a lesson through the lesson study approach, but also to engage in teaching that lesson in order to complete the lesson study cycle (M. Fernández, 2005).

MLS was first used with prospective mathematics teachers to explore gains in pedagogy and content knowledge during participation in MLS during two different semesters of a teacher education program (M. Fernández, 2005). To begin the study, participants were divided into groups of three and assigned a particular mathematical topic which they presented in an initial microteaching lesson to a small group of their classmates. Each group then analyzed the practice lesson and completed feedback forms, practicing the reflective portion of the lesson study cycle. Participants were then re-divided into new microteaching lesson study groups of three and provided with the overarching goal of designing lessons that "develop mathematics students' reasoning and ability to study patterns in discovering relationships or constructing concepts" (M. Fernández, 2005, p. 39). Each group was assigned a topic for its lesson. The topic was assigned by the instructor rather than selected by the group to ensure class members' unfamiliarity with the topic. This allowed the group to begin by researching the content of the lesson itself (M. Fernández, 2005). The MLS groups prepared their new lessons and presented them to selected classmates in a microteaching environment. The presentation was videotaped to be used in group analysis. Each group then met, discussed strengths and weaknesses of the lesson presentation, and agreed upon necessary modifications. The lesson was presented a second time and the cycle was repeated. Following the third presentation each MLS group prepared a final written reflective report for the instructor.

An important distinction between the microteaching lesson study experience and that of standard microteaching is that the prospective teachers worked collaboratively in a learner-centered environment, focusing on lessons to be presented in a learner-centered environment. This double exposure to the learner-centered concept places an emphasis on reform style teaching and learning. In applying the concept of the research lesson used in lesson study, the lessons presented by the prospective teachers became, not the typical skill-based lessons, but, rather, were problem based, once again emphasizing reform style teaching and learning.

Qualitative data collected included videotapes of the lessons, audiotapes of interviews and group meetings, observation notes, and reflective end-of-project reports completed by each group. These reports contained an outline of each group's lesson plan along with revisions made after each presentation and a reflective analysis of the process by group members. Survey data were also collected to establish knowledge of subject matter and perceptions of the MLS experience. All data were analyzed in relation to the overarching goal of creating student-centered lessons as well as examining pedagogy and content knowledge growth in the participants.

Findings reflected a significant shift in pedagogy toward student-centered lessons. This was demonstrated by the fact that, while over 80% of the prospective teachers were "telling" the mathematics students the relationships in the initial lessons, less than 20% were "telling" by the end of the lesson study phase. Content knowledge was also seen to increase. When the mathematics students participating in one lesson study group asked a question that the prospective teacher could not answer, her lesson study group searched for the answer and included it in the subsequent teaching of the lesson. In addition, the reported perceptions of the MLS experience were generally positive (M. Fernández, 2005).

In a subsequent study involving 74 prospective teachers participating in MLS, three additional themes emerged: connecting theory to practice, collaboration, and reflection (M. Fernández & Robinson, 2007). Participants appreciated the opportunity afforded by microteaching lesson study to apply the theories they were studying in the course into actual practice. They saw the benefit of working with a group of their peers and sharing their views in the process of evaluating the lessons. In addition, they recognized the importance of reflecting on a teaching experience (M. Fernández & Robinson, 2007). By offering the prospective teachers the opportunity to apply what they had learned, learn from each other, practice the art of reflection, and experience teaching in a student-centered environment, "prospective teachers perceived that MLS was a worthwhile and beneficial learning experience" (M. Fernández & Robinson, 2007, p. 207).

Summary

Incorporating technology into mathematics and science classrooms is important (NAS, 1996; NCTM 2000). For future teachers to be prepared for such inclusion, teacher education programs must provide opportunities for preservice teachers to develop technological pedagogical content knowledge (AMTE, 2006; Thompson, 2007). One possible strategy for providing these opportunities is through the use of microteaching lesson study (M. Fernández, 2005; M. Fernández & Robinson, 2007).

Since both technological pedagogical content knowledge and microteaching lesson study are relatively new concepts in educational research, the literature base for both concepts is limited. It was my hope to add to the literature base in both areas by investigating and reporting on the following research questions:

1) What changes in technological pedagogical content knowledge occur as preservice teachers participate in microteaching lesson study?

2) What aspects of microteaching lesson study afford opportunities for these changes in technological pedagogical content knowledge to occur?

3) What factors and barriers influence the changes in technological pedagogical content knowledge?

CHAPTER 3
METHODOLOGY

Prior Research Project

During my doctoral program I conducted a two-part supervised research project related to technology education for preservice teachers. The first part focused on the modeling of technology-enhanced instruction in a course for preservice teachers and the second focused on the same preservice teachers involved in microteaching lesson study (MLS). Summarized in two documents (Cavin, 2006a, 2006b), both portions of the research study involved primarily qualitative data collection through observations, interviews and course documents and focused on the development of technological pedagogical content knowledge (TPCK) in the preservice teachers. A brief description of the project is provided here to establish its impact on the dissertation research project.

Prior to conducting research on modeling, instruction in my technology course was primarily related to demonstrating technology and providing opportunities for the students to acquire the skills necessary to work with technology. The lessons were not specifically structured to provide opportunities for the preservice teachers to learn with technology or to teach with technology. In reviewing the literature related to modeling, I realized that modeling the use of technology in a learning environment increased the opportunities for students to develop knowledge that would transfer to their future classrooms (Rahal & Melvin, 1998; Roth-McDuffie, 1996). For the research project, I restructured my technology course to incorporate modeling in my instructional strategies, engaging the preservice teachers as students in using the technology to investigate mathematical topics. A lesson was included for each of a variety of technological tools, including graphing calculators, Excel, Geometer's Sketchpad, TI-Interactive, and several online tools. After each lesson the class discussed the pros and cons of incorporating technology into the lesson, modeling a portion of the lesson study concept.

The second part of the project, involving MLS, served as a pilot project for this dissertation research and provided valuable insight into the research design. The preservice teachers in the technology class were divided into three MLS groups, each containing three members. The group assignment was based primarily on student schedules. Providing opportunities for group meetings and instruction required coordination of blocks of free time for each preservice teacher with other members of his or her group. Students enrolled in the two sections of Mathematics for Liberal Arts I, a general education mathematics course offered on campus, agreed to serve as the classroom audience; thus a second scheduling consideration was the meeting time for the liberal arts mathematics classes. Each MLS group was allowed to select a lesson topic appropriate for the liberal arts course, and to develop a lesson using any form of technology. Once lesson plans were approved, one person in each group presented the lesson to one third of section one of Math for Liberal Arts I.

Technology class time was allocated for the review and modification of each lesson which a second member of each group taught to one-third of section two of the liberal arts class. Each MLS group then scheduled a time outside of class to discuss the second presentation. Final changes were made and the third member of each MLS group presented the group lesson to the members of our technology class. All lesson presentations were videotaped to allow group analysis of the lesson as well as preserving the data for future coding.

Three participants, one from each MLS group, were selected for in-depth case study analysis. Interviews were conducted twice during the semester. The first interview session took place following the participant's teaching of the group lesson. To identify the impact of modeling on the development of TPCK, this interview focused on the effect participation in the modeled lessons had on the decisions made in the development of the group lessons. To determine the relationship between participation in the MLS process and the development of TPCK, a second interview was conducted with the same three participants at the conclusion of the MLS process. All nine participants provided feedback through course documents which included video feedback forms and surveys. While findings from the data analysis did indicate development of TPCK as the preservice teachers participated in modeled lessons and microteaching lesson study (Cavin, 2006a, 2006b), the primary benefit of conducting the project was in realizing parts of the research design that worked well, and parts that needed to be changed in conducting the dissertation research described in the following sections.

Research Context

In effort to focus on participation in the microteaching lesson study process, this dissertation research used a group case study approach (Creswell, 2005). Participants were preservice teachers enrolled in EME 3410, Integrating Technology in the Classroom, at a small rural college. After existing as a community college for over 50 years, in 2003 the community college was granted permission to offer baccalaureate degree programs in secondary and middle school education, and officially became a college. EME 3410 is a required course for all students enrolled in the teacher education program at this college, and fulfills one requirement for alternative certification in many content areas. When the program was approved in 1993, I was asked to develop the curriculum for EME 3410, and during its four year history, I have been the sole instructor for the course.

All students enrolled in the course during the current term were informed of the purpose of the research project and that participation was strictly voluntary, in no way affecting the outcome of their course grade. They were informed that all data collected would be done so confidentially, and that the results would be shared with the participants at the conclusion of the study. All students enrolled in the class agreed to participate in the research project, and signed the appropriate consent forms (Appendix A). Two MLS groups, consisting of six students (three per group), were purposefully selected as case studies for this research. Using pseudonyms, the six participants will be identified as Margie, Chloe, Beth, Scott, John, and Todd. Further information on the individual participants as well as the formation of the MLS groups is provided in future sections. As a brief introduction, however, Margie was majoring in science education while the remaining five were mathematics education majors, and all six participants were in the junior year of their respective programs.

The course met twice each week in the technology lab for a total of three hours per week, two hours on Tuesdays and one hour on Thursdays. Technology resources available included 25 computers with Internet access, a teacher station with projection capabilities, and printers. Software installed on each computer included standard Microsoft Office 2003, TI-Interactive Version 1.3, TI-Connect Version 6.0, and Geometer's Sketchpad Version 2.0, with TI-SmartView Version 2.0 installed on the teacher station only. The education department owns five digital video cameras and video editing software. The department also owns a set of graphing calculators, calculator overhead displays, and a set of Calculator Based Rangers (CBRs) and Calculator Based Labs (CBLs) with multiple probes. Thus technology resources were not a limitation in conducting the research.

Preservice teachers were introduced to the goal of the research early in the semester. To help inform their knowledge of key aspects of the research, the preservice teachers were assigned readings that were subsequently discussed by the group during a class meeting. The assigned articles included, "Preparing Teachers to Teach Science and Mathematics with Technology: Developing a Technology Pedagogical Content Knowledge" (Niess, 2006), portions of the article "Promoting Appropriate Uses of Technology in Mathematics Teacher Preparation" (Garofalo, Drier, Harper, Timmerman, & Shockey, 2000), and sections of "Learning From Japanese Approaches to Professional Development: The Case of Lesson Study" (C. Fernandez, 2002). As they participated in learning experiences and provided feedback during the course, the TPCK definition provided a common ground for class discourse.

The actual course model contained the two components explored in my prior research projects, modeling and microteaching lesson study. During the first portion of the course, preservice teachers enrolled in EME 3410 experienced learning with technology as I modeled teaching with technology. In each lesson I modeled teaching strategies that incorporated the use of technological tools to engage the preservice teachers in exploring patterns through data analysis and functions. The modeled lessons were limited to explorations with data analysis and functions so that, when the preservice teachers began participating in microteaching lesson study, they had multiple exposures to technological tools that were effective in this area rather than a superficial exposure to a multitude of technological tools. Technology used in the modeled lessons included graphing calculators, Excel, TI-Interactive, TI-SmartView, TI-Connect, and Calculator Based Rangers (CBRs). It should be stated here that all technologies typically covered in EME 3410 were presented in subsequent lessons so that the participants received instruction on the full extent of the technology contained in the course syllabus.

Modeled lessons involved my incorporating the use of a specific technological tool in a mathematics lesson while the preservice teachers worked through the lesson as if they were students in a classroom setting. A basic lesson was presented first to introduce the use of the technological tool. In this lesson the preservice teachers focused on the skills required to make the technology work. A second, more in-depth lesson using the same technology was then introduced. The goal in this lesson was to engage the preservice teachers in exploring mathematical patterns and/or relationships using the technological tool. Several of the lessons used were developed for my prior research project related to modeling and microteaching lesson study, but many of the lessons were retrieved from such resources as issues of *Learning and*

Leading with Technology (ISTE) and *Mathematics Teacher* (NCTM). Two samples of the modeled lessons are provided in the following section.

Following each lesson, preservice teachers completed a lesson reflection form (Appendix B) which was used to facilitate group discussion of the lesson in relation to the overarching goal of the class MLS project; to engage the students in exploring mathematical patterns and/or relationships using technological tools to develop a rich understanding of mathematical topics. In focusing on the framework of the research (TPCK), the questions asked on these evaluation forms were related to the technology used, the teaching strategy used, and the benefit of each to each student's understanding of the mathematical concept presented. When participating in the modeled lessons the preservice teachers looked through the student lens. When reflecting on the lessons, the preservice teachers looked through the teacher lens. The distinction between the student role and the teacher role became so prevalent that several times during the semester the question was raised – "How should we look at this, as a student or a teacher?" While the lessons were not re-taught, feedback was saved for lesson modification in future semesters. This process was repeated several times, with various lessons, over a six-week period.

Modeled Lessons

Two of the modeled lessons are presented in this section as examples of the EME coursework so that the reader might gain insight into the technology and content used as the preservice teachers participated as students in technology-enhanced lessons.

Graphing patterns. The first lesson requesting feedback from the preservice teachers involved the use of a spreadsheet to explore the relationship between two columns of numbers representing two variables, x and y. Rather than using real-world data, the spreadsheet simply contained two columns with numbers partially filled in. As the number in the first column increased by a specific value, the number in the second column also changed. Preservice teachers were asked to fill in values in the second column until they could identify a pattern. As numbers were entered, the spreadsheet was programmed to respond with "correct" or "good job" when the value was appropriate. Once the pattern was identified, the preservice teachers were requested to enter a formula into the second column and were once again rewarded if the formula was correct.

There were, however, a few problems with this lesson. Of the three sets of columns, two worked fine, but one contained errors. In the second pair of columns when students entered correct values they did not receive feedback indicating a correct response. I instructed the preservice teachers to continue with the third column of numbers and fixed the lesson for the next presentation. While this was an unfortunate circumstance, it also provided a learning experience for the preservice teachers in relation to dealing with unexpected problems when using technology as an instructional tool.

In a group discussion following this lesson, feedback provided by the preservice teachers included the following points, related to technology, pedagogy, content, or an overlapping of these concepts.

> The blue column did not work. (Multiple responses)
>
> I needed more directions. (Margie)
>
> I needed directions on a handout. (John)
>
> I got immediate feedback before moving on to the next part. (Beth, Margie)
>
> Students (preservice teachers) were allowed to "play". (Chloe, John, Margie)
>
> Working in pairs (small groups) was useful. (Multiple responses)
>
> It would have been more time-consuming w/o the technology. (Multiple responses)
>
> Instruct students to press control home before saving the spreadsheet (so that the cursor will be in cell A1 when opened). (John)
>
> I would have used real world data after a few easy examples. The lesson was just a little too easy and may not have allowed the students to think critically. (Todd)

Steps. A second lesson involving feedback from the preservice teachers was a lesson taken from *Mathematics Teacher* (Peterson, 2006) and modified to incorporate the use of technology. The lesson involved building a set of "steps" using squares stacked upon squares (Figure 3.1).

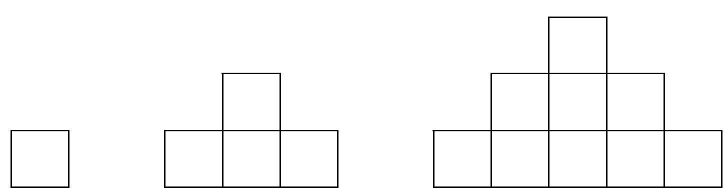


Figure 3.1 Steps pattern

The steps began with a first stage of a single row composed of one square, requiring a hypothetical single step to reach the top. The second stage was built by setting this single step on top of a new row consisting of three squares, creating a two-row pattern, requiring a two-step climb to reach the top. The next stage was created by adding a five-square row, for a total of 9 squares, requiring three steps to the top. The question was then posed, “If this construction pattern was continued, how many squares would be contained in a set of steps that contains 10 rows?”

The preservice teachers, working as classroom students, entered their data into a TI-Interactive data list and made a conjecture for a mathematical relationship. This relationship was then entered as a formula into TI-Interactive’s function grapher. Both the data and the function were graphed, and the window was adjusted as necessary. If the graph of the function passed through the data points, students were confident that their conjecture was confirmed.

Each member of the class was then asked to complete the following statement in at least two different ways. “As the number of steps to the top increases, the _____ also changes.” Responses from the group included the following:

Height

Number of squares on the bottom

Area

Perimeter

Line segments (toothpicks)

Points on the outside (intersection of EXACTLY TWO toothpicks)

Distance from center to the end (“Radius” of the bottom)

Number of blocks to the left of the center block

Number of boxes per level

All exterior corners (inside corners and outside corners but not the flat ones on the bottom)

All corners – all points of intersection

Number of rectangles

The class was then divided into groups of two, and each group selected one of the changes observed above with the goal of investigating any mathematical relationships between the number of steps (rows) and the observed changes. These values were entered into the TI-Interactive data list, the mathematical relationship was entered as a function, and a comparison was made. Group results were then shared with the class.

To practice the lesson analysis phase of the MLS process, each preservice teacher completed a lesson evaluation form, and a group discussion followed. Sample comments from the preservice teachers related to technology, pedagogy, content, and overlapping areas are as follows:

> I needed more time. (Beth)
>
> This would have been better in two lessons. (John, Scott)
>
> Using technology allowed the lesson to move more quickly. (Scott)
>
> There was no need for technology in this lesson. (Margie)
>
> The lesson would have been better with Excel and/or the TI-83. (Todd)
>
> TI-Interactive was better, easier, and more to the point. (Chloe, John)
>
> Without technology the students would have a better understanding of "plot building or graphic analysis." (Scott)

Setting the Stage for Microteaching Lesson Study

To set the stage for the MLS process, several preliminary tasks were conducted. These included securing the teachees, conducting task-based interviews, collecting biographical data from the participants, and forming the MLS groups. Each of these tasks is described below.

Securing the teachees. Following the design of the pilot project, the original plans for the current study included securing students enrolled in liberal arts mathematics to participate as classroom students, or "teachees", in the lessons presented by the preservice teachers enrolled in the technology class. This proved to be difficult for several reasons. There was only one section of Math for Liberal Arts I offered during the current term. As a result, teaching the same lesson twice to two different sections was not an option. There were two sections of Math for Liberal Arts II, but they were both called upon repeatedly to serve as teachees for the preservice teachers enrolled in the mathematics and science methods classes. The instructor for the liberal arts course stated that she would adjust her schedule one more time if necessary, but requested that I consider other options.

A quick look at the schedule of mathematics classes for the term showed that two sections of College Algebra were taught by the same instructor, one at 8 am and the second at 12 pm. This instructor was approached and she agreed to adjust her teaching schedule to allow her students to serve as teachees. I personally visited these two classes and explained the purpose of their participation: to provide authentic teaching experience for the future teachers, and to allow me to observe the preservice teacher's use of technology in teaching the lesson. The reception was quite positive. The teachees were interested, supportive, and agreeable, and all signed permission forms (Appendix A).

Conducting task-based interviews. Task based interviews were conducted to investigate the participants' existing TPCK. During this interview participants performed a variety of tasks (Appendix C). The goal was to explore some of the decision-making processes that the preservice teachers used in each of the following areas: identifying available technological resources that could be used in presenting a given mathematics lesson, making the decision to include (or not include) technology in a mathematics lesson, and determining whether use of a specific technological tool effectively enhances student learning in that lesson. The interviews were conducted in my office and all the technological tools available in the technology lab were available. Audio recordings were made for future analysis.

In the first part of the interview, the participants solved a system of equations by hand using paper and pencil, and then solved a more complicated system of equations using the technology of their choice. In the second part of the interview, the participants were presented with a typical word problem from an Algebra I text book (Gerver et al., 1997) and were asked to demonstrate how they would present this word problem if they were teaching an Algebra I class. The only requirement was that they use technology in the process. In the third and final part, participants used an on-line, interactive applet to solve a system of equations and were questioned about their opinions on the effectiveness of this applet.

During each part of the interview, I asked the participants to describe what they were doing so that their thoughts could be recorded. I also saved any documents they created either in paper form or as files on the computer along with my fieldnotes made during the interview. These interviews lasted approximately forty-five minutes and were used primarily for comparison purposes at the conclusion of the project.

Background data collection. While this dissertation research project was based primarily on an analysis of qualitative data, some quantitative data were collected early in the course related to the preservice teachers' personal histories, prior technological skills, and beliefs toward both student learning and the use of technology in the classroom. This information was used in assigning students to MLS groups as well as for comparison purposes in conducting the data analysis.

A brief personal history was collected during the first week of the term via the student information form completed by all students enrolled in the course (Appendix D). This contained contact information such as phone number and email address (required for the course). The preservice teachers also provided a brief paragraph about prior teaching experiences, experiences using technology, and expectations of the course. They also ranked their own level of technological literacy on a scale of 1 to 10.

To examine the basic technological skills of the participants, a survey of comfort level with technology related tasks was also completed during the first week of the course, patterned after the self-efficacy survey used by Kinzie, Delcourt and Powers (1994), and Milbrath and Kinzie (2000). The self-efficacy for computer technologies (SCT) survey contained questions related to word processing, communicating via email, searching CD-Rom data, spreadsheets, creating and managing data bases, and use of statistical packages. Internal consistency reliability (alpha) estimates for the six factors of the SCT ranged from .95 for word processing to .99 for data base program (Kinzie et al., 1994). The SCT was modified for my research to address the areas of accessing web sites, navigating the internet, navigating the intra-net (the school's local network), and using PowerPoint. The intent was to determine the comfort level of the various participants in relation to a variety of technological activities. The preservice teachers responded using a 6-point Likert scale where a response of 0 indicated the participant had "never performed the specific task" and 5 indicated the participant "performed this task often and could teach/help others." Data collected indicated that Todd, Beth, Margie, and Scott considered themselves the most technologically literate among the group as indicated in Table 1.

Table 1

Technology Literacy Levels

	Participant					
	Beth	Chloe	John	Margie	Scott	Todd
Score	150	107	91	149	124	157

Just prior to the implementation of the MLS process, additional data were collected. To investigate beliefs toward student-centered learning, the preservice teachers completed a Learner-Centered Battery, retrieved online from the testing manual located at http://www.eric.ed.gov/ERICWebPortal/custom/portlets/recordDetails/detailmini.jsp?_nfpb=true&_&ERICExtSearch_SearchValue_0=ED422377&ERICExtSearch_SearchType_0=eric_accno&accno=ED422377 (McCombs, Lauer, & Peralez, 1997) and used with permission (Appendix E). The preservice teachers responded to items using a 4-point Likert Scale with 1 = strongly disagree, 4 = strongly agree, and no allowance for a neutral response. The thirty five questions were divided into the following three factors.

1) Learner-centered beliefs about learners, learning, and teaching.
2) Non-learner-centered beliefs about learners.
3) Non-learner-centered beliefs about learning and teaching.

Based on pilot testing involving 908 teachers in grades K-12 from various ethnic backgrounds, grade levels, and experience, the internal consistency coefficient (Cronbach's alpha) for each of the three factors was .87, .83, and.82 respectively.

According to the testing manual, feedback was prepared for the participants during the pilot test reflecting scores that were indicative of "the general direction of scores for learner-centered teaching based on current validation data" (p. 67). Samples included in the manual indicated that scores in each factor were considered high if they were at or above 3.2. In examining the participants' scores in my data, there was a more substantial break in the scores at 3.1 (with the next lowest score being 2.86). Consequently, a score of 3.1 was used as the cut-off point for this research data to indicate that the preservice teacher held a strong belief toward the corresponding factor (Table 2).

Table 2

Scores on Learner-Centered Beliefs Survey

	Participant					
Learner-Centered Factor	Beth	Chloe	John	Margie	Scott	Todd
Learner-centered beliefs about learners, learning, and teaching	3.21	2.86	3.10	2.64	2.43	3.36
Non-learner-centered beliefs about learners	1.67	1.89	2.40	2.22	2.44	2.33
Non-learner-centered beliefs about learning and teaching	2.00	3.25	2.80	2.50	2.67	2.58

Using these guidelines, Beth, John and Todd indicated strong learner-centered beliefs about learners, learning, and teaching while Chloe indicated strong non-learner-centered beliefs about learning and teaching. None of the participants indicated strong beliefs in the factor related to non-learner-centered beliefs about learners.

To identify the preservice teachers' prior experiences with technology in an educational environment as well as the value placed on the use of technology in an educational environment, an additional researcher-developed survey was used (Appendix F). This survey asked the preservice teachers to respond to three statements posed in relation to a variety of technological tools including the World Wide Web (WWW), spreadsheets, word processing, TI-Interactive, Geometer's Sketch Pad (GSP), Calculator Based Rangers (CBRs), and the graphing calculator. The three statements were as follows.

1) It is important to incorporate this technology in the classroom.
2) I am comfortable using this type of technology for personal use.
3) I am/would be comfortable using this type of technology in the classroom.

The preservice teachers responded using a 4-point Likert scale ranging from 1 = strongly disagree to 4 = strongly agree. There was no provision for a neutral response. Strongly agree responses to all three questions (a score of 12) would indicate both high importance and high comfort level for the corresponding technological tool. Two additional open-ended questions for each technological tool allowed for feedback as to how the technology had been used in a classroom setting by the preservice teacher as well as his or her attitude toward how the technology should be used in the classroom. The preservice teachers completed the statements, "I have used this type of technology in a classroom setting in the following way(s)," and, "I believe this type of technology should be used in the classroom in the following way(s)." Areas receiving highest values of importance and comfort level among the participants were the World Wide Web and the graphing calculator, with the lowest scores in the Calculator Based Ranger (CBR) and Geometer's Sketch Pad (GSP).

Participants

A summary of the background data for each individual participant is presented in the following sections to help convey the technological, pedagogical and content-related knowledge of the participants prior to beginning the course. The information is presented in two groups, representing the two groups eventually established for the MLS process, and named for the technological tool eventually incorporated into their respective lessons. The first is the TI group, named for their use of the TI-83 graphing calculator, followed by the XL group, named for their use of Excel.

TI group. The following paragraphs contain information collected on the TI group. Members of this group are Chloe, Beth and Todd.

Chloe. Chloe earned an Associates of Arts degree in 1999, and returned in 2005 to begin pursuit of her teaching degree. By the time she enrolled in my technology class, she had taken most of her required mathematics classes and several of the required education classes. She was concurrently enrolled in a methods class, Teaching Secondary School Mathematics, thus studying teaching methods while studying the concept of teaching with technology.

One thing she had not completed, however, was the required prerequisite course on Introduction to Educational Technology. While she received a waiver for that course based on her work experiences between 1999 and 2005, her self-assessed level of technology skills was low in comparison to most of the other participants. In the use of technology to complete personal tasks, she self-scored 107 out of 170 (the second lowest in the group), and ranked her own technology literacy level at 5 (out of 10) on her biographical data form. When completing the feedback on the use of technology in the educational arena, her only comments were in the use of PowerPoint, indicating that it was important to use as an organization tool.

Chloe had a somewhat unique exposure to actual teaching experiences. She was employed on campus as a supplemental instruction leader, a program designed to support students enrolled in courses designated as high-risk for Ds, Fs, and withdrawals. The course and section were determined by the Quality Enhancement Program committee for our college, based on prior years' grade ranges. The class to which Chloe was assigned was one of my sections of Elementary Algebra. Her duties required that she sit in on the instruction for the class and then facilitate regularly-scheduled "supplemental instruction" sessions for the students in that class. While the sessions were designed for the students in that particular section, they were open to any student taking the Elementary Algebra course. During these sessions Chloe reviewed the material presented during the regular class using a variety of teaching strategies such as initiating small group work, having the students work on the board, and assisting with the preparation of study notes. As indicated above, Chloe's responses on the survey related to student-centered beliefs indicated strong non-learner-centered beliefs about learning and teaching (3.25 of 4.00), which reflected Chloe’s teacher-centered belief.

Beth. Beth began her college career as a computer science major, and had taken multiple computer classes which included Introduction to Computer Programming, Introduction to Computer Systems, Introduction to Data Base and Introduction to Microcomputer Use along with the required Introduction to Educational Technology. She ranked herself at 7 out of 10 in technology literacy on the student background form, and self-scored 150 out of 170 relating to personal use of technology. This strength in the area of technology was confirmed through conversations during several of the group meetings where she showed other members in her group how to perform tasks on the graphing calculator, and in her use of technology to modify her group’s MLS lesson handouts.

Beth had previously completed mathematics coursework through the Calculus II level and was concurrently enrolled in Calculus III and Differential Equations. She had taken the three pre-requisite education courses, and was enrolled in two additional education classes, but had taken no methods courses and had no formal teaching experience. She had, however, worked on campus for two years in mathematics labs doing one-on-one tutoring.

In the self analysis of using technology in the educational arena, Beth's responses revealed that she held the strongest beliefs among the participants on the importance of, and comfort with, nearly all the various technological tools. However, her open-ended response to TI-Interactive – “This allows the student to see what you are typing onto the calculator so they can easily follow you as a teacher,” – indicated that she was confused as to what TI-Interactive really was. Her reported confidence and comfort levels may have actually been associated with TI-SmartView, a technological tool used in class but not specifically addressed in the survey. Results on the learning survey indicated that Beth’s pedagogical beliefs reflected learner-centered beliefs about learners, learning, and teaching, averaging 3.21 out of a possible 4.0.

One additional factor influencing Beth’s performance during the semester was related to the death of a close family member early in the term, which resulted in several weeks of missed class, as well as an emotional drain. She fell behind in several classes, but did complete her teaching responsibilities for the MLS project as well as the final surveys and interviews.

Todd. Todd began his (community) college career in 2001 with dual enrollment coursework in mathematics and English. He enrolled on campus full time in 2002. However, his education was postponed twice due to service in Iraq through the National Guard. His original plans were to pursue a degree in Business Administration. In the Fall of 2005 he changed his major to Mathematics Education. He began taking the prerequisite coursework, and completed requirements for his AA degree in 2006. As of the current semester he had taken or was concurrently enrolled in his mathematics courses through Differential Equations, but had not taken any of the methods courses to date.

Todd was a volunteer tutor at a local civic center for an after-school program and worked as a substitute teacher on his non-class days. He indicated on his biographical data form that he had taught lessons on "similar triangles, integers and other middle school math," and survey results indicated strong learner-centered beliefs about learners, learning, and teaching (3.36 out of 4.0).

In reporting his technological expertise, Todd stated that he was "very comfortable" with technology; he ranked himself at a level of 8.5 out of 10, and he was working toward MOUS certification in Word and Excel. He scored 157 out of 170 on comfort levels with technology tasks, the highest self-ranking among the participants.

XL group. The following section provides background data collected on the XL group. Members of this group are Margie, John, and Scott.

Margie. Margie was the only science major among the participants. She had completed the secondary science education methods class and practicum, during which she taught three-day units in biology (genetics) and chemistry (water pollution). She worked on campus as a supplemental instruction leader for one section of Earth Science, as Chloe did for Intermediate Algebra.

Margie ranked herself at a level 8 of 10 in technology literacy, and self-scored 149 out of 170 in performing computer related tasks. She indicated a weakness in only three areas: using equation editor, using macros, and editing digital videos. She strongly agreed that she was comfortable using word processing, spreadsheets, PowerPoint, and graphing calculators for personal use, and agreed on both comfort with and importance of their use in the classroom, adding that the "material to be covered [should] determine whether or not this should be used in actual instruction."

An overall grade point average of 3.66 is indicative of Margie's content background. She had completed coursework in microbiology, anatomy and physiology, ecology, plant biology, and was enrolled in a genetics course for the fall term. Her responses on the survey did not indicate any strong belief in either student-centered or teacher-centered learning.

John. John, who was currently teaching 7th and 8th grade mathematics at a small private school, had the highest number of actual teaching hours among the participants. His classes were small, but contained a wide variety of ability levels; thus he used primarily small group instruction. His responses to the survey indicated that he held strong learner-centered beliefs (3.1) about learners, learning, and teaching.

John ranked himself at a level 3 of 10 in technology literacy, stating that he knew "just enough to survive" and that his goal for the course was to "get beyond survival." He was the participant indicating the lowest importance/comfort level with technology use in the educational arena. None of his responses were in the "strongly agree" category, indicating that he had no self-perceived strengths with technological tools. He "agreed" that he was comfortable only with the generic tools of the World Wide Web, PowerPoint, spreadsheets, and the graphing calculator. In response to the use of technology to perform specific tasks, he self-scored 91 out of 170, the lowest among the participants.

As a secondary mathematics education major he had completed through Calculus III and was concurrently enrolled in both Differential Equations and Number Theory. He had completed the secondary mathematics methods course, and planned to take Modern Geometries in the summer term.

Scott. Scott was another "returning" student in the class. He earned a vocational certificate in telecommunications in 1999. The course work required for that program included Introduction to Computer Programming, C++ Programming, and two internet/systems courses, in which Scott made all A's and B's. He returned to our (community) college in 2002, completing the requirements for his Associates of Arts degree in December, 2003. In 2006 he began working towards his teaching degree in secondary mathematics. During his off time, Scott served in the Navy, where he worked in electronics and did some computer programming. With all this computer-related background, he still rated himself at only 7 out of 10 in the area of technology literacy, and scored 124 out of 170 in the area of technology-related tasks. In the use of technology in the educational area, Scott indicated he was comfortable with word processors, spreadsheets, PowerPoint presentations, and the graphing calculator, and added Maple to the list in the "other" category.

In the content area, Scott had completed through Calculus III and was enrolled in Number Theory for the summer term. He had taken the secondary mathematics methods course and completed his practicum at the local high school. His responses to the student-centered learning survey indicated that he was neither strongly student-centered nor strongly teacher-centered, with scores of 2.43, 2.44 and 2.67 in the areas of learner-centered beliefs about learners, learning, and teaching, non-learner-centered beliefs about learners, and non-learner-centered beliefs about learning and teaching respectively.

Forming the groups. The six participants were divided into two groups with three members each. The first step in forming the groups involved assigning Margie and Chloe to separate groups. When small group work was assigned during the technology class, Margie and Chloe always paired up. They worked quite well together, addressing all the requirements of any given task, completing the work on time, and doing so in a professional manner. For this reason, it was considered important that these two preservice teachers be assigned to separate MLS groups, thus assigning an organized, task-oriented individual to each group.

It was considered important that someone with an interest in science and/or real-world applications be assigned to Margie's group, to complement her science interests. Early in the term John offered to be in her group since part of his work-related responsibilities (teaching at the private school) included helping his students with their science. In addition, he had intentions of pursuing teacher certification in integrated mathematics and science curriculum. In considering their background data, John had self-reported strong student-centered beliefs but less technology expertise, while Margie had self-reported strengths in working with technology, but was relatively neutral in her student-centered learning scores. Both participants had taken methods courses in their content areas, and both were high achievers based on cumulative grade point average. This group could be completed with Beth, Scott or Todd each of which self-reported relatively strong technological skills that would provide balance in the area of technological expertise. The final decision in placing the third member rested primarily on two key factors: previous experience and free time schedule. Scott was selected to work with Margie and John. It was anticipated that his prior real-world experience through his Navy career would complement their interests in integrated curriculum, and the free-time blocks indicated on the schedules of these three preservice teachers were compatible. Because of work related responsibilities, John’s available time was limited to afternoon hours. According to their schedules, Scott and Margie had similar free time, allowing for group meetings during afternoon hours.

That left Chloe, Beth, and Todd as members of the second group. These three members also had some common characteristics. All three had experience with tutoring in some fashion. Beth worked in the school mathematics labs, Chloe worked with the supplemental instruction program, and Todd participated in volunteer tutoring programs. Since Chloe and Beth both worked for the teacher education department, it was anticipated that their schedules could be flexible since their employers would understand the nature of their responsibilities to their MLS group. Todd had several outside obligations, but typically managed to rearrange his schedule when necessary in order to attend meetings for group projects.

Microteaching Lesson Study Process

With the groups formed, the class was ready to begin the microteaching lesson study (MLS) process. The steps used in the microteaching lesson study process were a combination of the lesson study process (e.g., C. Fernandez, 2002; Lewis & Tsuchida, 1998) and MLS (M. Fernández, 2005; M. Fernández & Robinson, 2007).

Step One: Goal Setting and Planning the Research Lesson

To begin the process, an overarching goal for the research lesson had to be established. Due to time constraints and the limited experience of the participants, I preset the overarching goal as follows: to engage the students in exploring mathematical patterns and/or relationships using technological tools in order to develop a rich understanding of mathematical topics.

Each group was given the opportunity to select their own lesson topic, with the restriction that it was suitable for a College Algebra class, and that it met the overarching goal stated above. Three class periods (one week of class meetings) were designated as time for the groups to work on selecting and developing their lesson plans, using the form developed for lesson study (Appendix G). It was made clear that additional time needed to complete the lesson plans, watch the videotapes, evaluate the lesson, and make modifications would have to be coordinated outside of class time. This was the first major outside assignment for the class. Prior to the MLS process, the majority of the course obligations had been completed during regularly scheduled class time. A due date for the lesson plan draft was set for the following Wednesday, allowing seven school days for the groups to complete the task. I provided feedback and allowed the remainder of the week for the groups to finalize and submit their first lesson plans.

Step Two: Teaching the Research Lesson

The first teaching of the MLS group lessons was done the following Monday with the 12 pm College Algebra class. Prior to teaching the lesson, each MLS group was responsible for setting up all technology, making sure it worked in the assigned classroom, and securing copies of any handouts needed. I was responsible for securing the videotaping equipment and had it ready in the classrooms before the lessons began.

I also procured a copy of the class roll from the instructor so that the preservice teachers would know how many copies of materials should be made, and could prepare individualized "homework passes." These passes were given to the teachees as a thank-you for participating. With prior agreement from the College Algebra instructor, these passes could be turned in any time during the remainder of the semester in lieu of an incomplete homework assignment.

I met the teachees in their classroom and split them into two groups using the odd and even numbered lines on their class roll. The odd numbered students remained in their classroom with Todd, and the even numbered students went to the technology lab with John. The teacher for the College Algebra class remained with Todd's group and helped with the videotaping of that lesson. I went to the lab and videotaped John's lesson.

When the lessons were completed, I made copies of the videotapes and distributed them to the MLS group members.

Step Three: Discussion of the Research Lesson

The MLS groups were allowed time during our next regularly scheduled class meeting to discuss their lessons. Each member of the group was required to observe either the lesson or the videotape prior to this meeting and complete a reflection using the lesson feedback form (Appendix H). The form was designed to focus the feedback on the mathematics students' thinking and their needs, as well as the accomplishment of the overarching goal. To provide information related to the research questions, the feedback form focused specifically on the use of technology and pedagogy as they related to the content of the lesson presented. Without this structured focus, it is likely that preservice teachers would focus more on themselves (or the individual teacher presenting the lesson) rather than student learning and the effective use of technology in the lesson (M. Fernández, personal conversation, 2006).

By holding this meeting during the regularly scheduled class period, I was able to circulate and participate in the group discussions. Preservice teachers were reminded of the overarching MLS goal: to incorporate technology in such a way that the students were engaged in exploring mathematical patterns and/or relationships using technological tools to develop a rich understanding of mathematical topics. If this did not happen, the groups were to consider what options might help their lessons accomplish this goal. Voice recordings were made during these discussions, which facilitated the data analysis process.

Step Four: Consolidation of Learning

As the groups agreed on changes that would help to achieve the overarching goal, the changes were incorporated into the lesson plan, and the second member of each group prepared to teach. The 8:00 am College Algebra group was once again split based on odd and even numbers on the roll, with half the group participating in each lesson. The College Algebra teacher and I switched videotaping duties this time so that we could each directly observe one presentation of each MLS group lesson. The group lesson videotapes were copied, secondary feedback forms were completed (Appendix I), and the groups met to evaluate and modify the lessons as needed. These meetings were held outside of class time, and I was able to participate in one group's meeting but not the other. As with all group meetings, voice recordings were made and used in the data analysis process.

Final changes were made in the group lesson plans, and the final teaching took place during a regularly scheduled two-hour class meeting of the EME class, with the EME students as the teachees. Descriptions of the group lessons along with the changes made during the MLS process will be discussed in the following chapter.

Wrap Up

After the final presentation, each group compiled an electronic folder representing the history of their group's lesson. This folder contained a copy of the lesson plan along with any handouts, teachee feedback forms, and computer files used in teaching the lesson (Appendix J). Any changes made between the first and second presentation were indicated in red, and changes between the second and third presentation were indicated in blue. Yellow highlighting in any document was used to indicate material that had been deleted. Specific discussions related to the changes were saved in the audio recordings, and reasons for the changes were summarized in the notes column on the final lesson plan. Copies of each MLS group member's lesson feedback forms were also saved into the group's folder, with the exception of Beth's (who did not complete the forms due to personal family circumstances during the semester).

Each member of the class also completed an individual, confidential, MLS feedback survey (Appendix K). Adapted with permission (M. Fernández, 2005), this survey was designed to obtain feedback from the participants on their perceptions of the overall MLS process. These surveys were emailed directly to me, rather than saved to the group folder, as they often included comments about other group members. A schedule for conducting final interviews of participants was made, and finial interviews were conducted. An interview protocol was used that contained questions to be asked of all participants, with additional questions to be asked of each individual participant. These personalized questions were used to clarify individual feedback received previously during the MLS process (Appendix L).

Data Collection and Analysis

Data Collection

Data collection was conducted throughout the entire semester. In addition to the personal information described above, data collected prior to beginning the MLS process included course documents such as feedback on the modeled lessons and digitized audio recordings of the task-based interviews. During the MLS process audio recordings were made of all group meetings, and videotapes were made of the individual teachings of the group lessons (6 lessons in all). I kept fieldnotes from the group sessions I attended and the lessons I personally observed. I also made several memory dumps via the voice recorder, creating audio "comments" (Bogden & Biklen, 2003, p 151). Both audio recordings and fieldnotes were made during the final interviews. To assist with the data analysis, audio and video recordings were transcribed, and the fieldnotes were summarized.

As mentioned above, each group also submitted an electronic version of its lesson plan, containing modifications during the MLS process, handouts, and the groups' own lesson feedback forms. These folders were saved, and documents that were emailed to me during the MLS process such as drafts of lesson plans, or requests for feedback were electronically added to the folders. Additional documents saved in hard copy included the worksheets and feedback forms completed by the teachees. The combination of transcriptions of audio and video recordings, course documents, and fieldnotes provided for triangulation of data.

Data Codes

Formal analysis of the data was conducted using the framework of TPCK as a guide. This framework contained two key references. The first consisted of Grossman's (1988, 1989) characteristics of PCK as modified by Niess (2005) for TPCK, paraphrased as follows:

- an overarching concept of what it means to teach a particular subject in which technology is integrated into learning;
- knowledge of instructional strategies and representations for teaching specific topics with technology;
- knowledge of students' understandings, thinking, and learning with technology in a particular subject;
- knowledge of curricula and curriculum materials that integrate technology with learning in the subject area. (Niess, 2005, p. 511)

Data were examined for evidence of these forms of knowledge.

The second reference used was the TPCK coding scheme initially developed during my prior research projects (Cavin, 2006a, 2006b) and modified during the current research study. This coding scheme (Appendix M) expanded the overlapping-circle representation of the TPCK framework established by Mishra and Koehler (2006) to include various state and national standards in the areas of technology (ISTE, 2000a, 2000b), pedagogy (Florida Department of Education [FDOE], 2003), and content (NCTM, 2000). These standards were employed to help identify participants' actions that were related to the individual areas of technology, pedagogy, and content; the overlapping areas of technology and pedagogy, technology and content, and pedagogy and content; and the overlapping of all three areas representing technological pedagogical content knowledge. The application of these standards to the coding of the data provided cues to help identify observable behaviors or verbal responses that were indicative of the various components of TPCK.

In the table created to accommodate the coding scheme (Appendix M), each standard was labeled with a code to identify the focus area (T, P, C, TP, TC, PC, and TPC) and parenthetically labeled with a code to identify the source. For example, TPC1, which states, "Use the materials and technologies of the subject field in developing learning activities for students (F8)," is the first code in the overlapping area of technology, pedagogy, and content, and F8 indicates that the source is the eighth indicator of the technology standard of the Florida Educator Accomplished

Practices (FDOE, 2003). These codes were used in the data analysis process and have been included for reference in the discussion of the findings and conclusions.

Data Analysis

I began the data analysis process by examining group data for the TI group in chronological order, beginning with the audio recordings from the group meetings related to the development of their lesson, followed by the individual feedback forms from the first teaching of their lesson. This was followed by the audio recording from the group meetings related to the reflection on the teaching of their lesson and the decisions they made toward modification of the lesson. This cycle was repeated with the second teaching, and was followed by the final individual surveys related to the MLS process and the individual final interviews. Since the focus was on the group decisions related to reflection on and modification of the group's lesson, the video recordings of the individual teachings of the lesson were examined for content and used for triangulation of findings, but were not specifically coded.

In the initial process of data analysis, data chunks were coded as relating to technology, pedagogy, content, or any combination of these, using the standards-based coding scheme as a guide. Once this initial coding was complete, the data were reanalyzed looking for any themes related to the research questions. Close attention was paid to data coded as TPC, in particular looking for any evidence of factors that influenced the TPCK-related decisions made by the group during the MLS process.

Once data for the TI-group was analyzed, the process was repeated with the data for the XL group. This was followed by an across-case data analysis, using a concept map (Miles & Huberman, 1994) to uncover interrelationships among the data and identify emergent themes. Coding of the data using the TPCK framework and standards-based coding chart, along with the identification of emergent themes did help to identify findings related to what changes in TPCK had occurred. Further investigation was needed, however, to address how microteaching lesson study afforded the opportunities for these changes to occur.

This portion of the analysis focused on the responses to the individual surveys reflecting on the preservice teachers' experiences during MLS process, along with the final interviews. In approaching TPCK development from a constructivist perspective, the context of the learning environment in which the development occurred was considered to be an important aspect during data analysis. When individual participants "agreed" that certain experiences were "helpful," group data were used to confirm that TPCK development did occur as those experiences were taking place. Researcher fieldnotes and observations were used to triangulate these findings. To further investigate the factors and barriers involved in the development of TPCK, resources related to teacher beliefs about mathematics (Hiebert & Lefevre, 1986; Skemp, 1978, 1987), teacher beliefs about technology (Ertmer, 2005; Ertmer, Ottenbreit-Leftwich, & York, 2007), and teacher thought processes (Clark & Peterson, 1986) were explored. A summary of the various data sets analyzed along with their primary contributions to answering the individual research questions is provided in Appendix N.

Credibility

Several techniques were used to enhance credibility. As I examined the data, I met with my major professor on several occasions, outlining my findings. We discussed the supporting data, which modified or expanded my thinking in several cases. I then reexamined the data and continued to summarize my findings. I also went back to the participants on several occasions, clarifying statements contained in feedback forms and recorded during group meetings.

One additional effort made to enhance credibility involved the use of a critical friend. I sent several transcripts of my data, along with my coding scheme, to a fellow researcher in the area of TPCK, Dr. Kathy Shafer. She holds a PhD in Mathematics Education and was a recipient of the outstanding research project from AMTE for her work with preservice teachers using technology. She coded a final interview transcript using the T, P, C, TP, TC, PC, or TPC coding scheme which I then compared to my own coding. The first step was to exclude several of her codes from the comparison as she coded focusing on the individual being interviewed as the specific case, whereas I coded based on the group case. I have saved her codes, however, for future analysis of the participants on an individual basis.

To continue the comparison, I applied colors to the data cells, using green to indicate where our codes matched exactly, category (T, P, C, TP, TC, PC, or TPC) and subcategory, and yellow to indicate where our codes were in the same category but a different subcategory representing a specific behavior. One example of a "yellow" coding occurred in response to a question about the calculator screen displayed for the teachees (the EME students). The interviewee stated that, "I was looking more at the large screen that we had up there and following it. But that probably would have allowed them to see everything at once, if the other two small screens had contained L1 or L2." I had coded this as TPC5, which was stated as, "Select or create mathematical tasks that take advantage of what technology can do efficiently and well," while she had coded it as TPC6 which was stated as, "Reflect on the use of technology in presenting the topic and make modifications as needed." Kathy had focused on the process of reflecting while I had focused on the conclusion drawn from the reflection, both of which provided similar evidence of TPCK. In addition to coding the data based on the coding scheme, Kathy observed several emergent themes in the data. Codes she added that coincided with mine included diversity, procedural mathematics, and modeling. When tallied, our codes were in the same category 94% of the time. Of our matching codes, only 36% were in the same category with a slightly different subcategory (coded yellow). While only one interview was compared, there is every reason to believe that coding additional data would yield similar results.

CHAPTER 4
FINDINGS

Within Group TPCK Changes

Once the groups were formed, they began to work as two separate units. Development of each group's lesson began during the two-hour brainstorming session during the regularly scheduled two-hour technology class period. The only set criteria for content of the lessons were that the topic was appropriate for the teachees, the College Algebra class, and that the lesson incorporated the use of technology to meet the overarching goal of the MLS project: to engage the students in exploring mathematical patterns and/or relationships using technological tools to develop a rich understanding of mathematical topics.

Beginning with this first developmental meeting and progressing through the completion of the final surveys, the interaction between the members of each MLS group is described in the following sections, focused on the development of the lesson itself rather than the teachings of the lesson by the individual members of the MLS groups. By examining the progression of the lessons and the changes that took place in their designs throughout the MLS process, the changes in TPCK of the participants is identified. While this section does contain references, as deemed appropriate, to specific aspects of the MLS process that afforded opportunities for these changes to occur, as well as factors influencing the decisions of the preservice teachers, the focus in this section is on what changes in TPCK occurred. A more in-depth focus on aspects of MLS, factors, and barriers is reserved for future sections.

The Case of the TI Group

In this section I describe the basic procedures the TI Group used in securing, developing, presenting, and modifying their MLS group lesson to serve as a background for the analysis of TPCK development in the group members. Emphasized in this section are technological, pedagogical, and content-related decisions made by the group.

Selecting a lesson. The TI group began by searching the internet for topics related to algebra and came up with several options. In the initial process of selecting the topic, conversations from this first group meeting indicate that several factors influenced their decisions. A preliminary discussion of a "cool" lesson using Geometer's Sketchpad to explore the sum of the angles in a triangle was quickly ended when the group realized none of them had been exposed to that particular technology and, consequently, were not comfortable with its use (although by the end of the semester the Sketchpad software had been presented in their technology class).

They continued to explore and found several lessons related to mean, median, and mode. One involved the use of Excel. They made a decision to eliminate that lesson also because "it took [them] three hours to do [their] first Excel spreadsheet." This indicates that one factor in the decision to exclude Excel from their group lesson related to the length of time required for introducing the technology to a group unfamiliar with the software as compared to the time allotted for their lesson, exemplifying a technological pedagogical decision.

After further searching on the web, the TI group located a lesson at TI.com using the TI-83 (or TI-84) calculator in exploring experimental and theoretical probability. The lesson involved a hypothetical student, Nathan, using the random integer function on his calculator to select 20 random integers, each between 1 and 4, that simulated randomly selecting answers to a multiple choice test. These numbers were to be stored in a calculator list (L2), compared to the answer key for the test (provided in the lesson outline), and used to generate a test score. By running this simulation multiple times, the class would collect data on the number of times Nathan passed the exam, and compare this experimental probability to the actual theoretical probability of passing a 4 option 20 question multiple choice exam.

The document retrieved from http://education.ti.com/educationportal/activityexchange/Activity.do?aId=4254 contained a brief narrative describing Nathan's decision to use his calculator to randomly guess answers on the test when faced with taking a test for which he had not studied. It contained step-by-step instructions for entering the "correct" answers into the calculator's L1 list, simulating Nathan's process of guessing, then storing those guesses into the L2 list, testing whether Nathan's answers matched the correct answer, and summing the number of correct answers. It also contained a chart for summarizing the data, and calculating the mean, median, and mode of the individual simulated test scores. The TI group was interested in using the lesson, but discussion indicated that it was important to the group that they were comfortable with the material before presenting it to the teachees. Beth stated, "Let's see if we can master it. Then it would be a good thing to do [for our lesson]." After working through it themselves, they agreed to use it as the foundation for developing their own MLS lesson, but that it needed some modification.

Pre-teaching lesson development. In three subsequent meetings prior to the first teaching of the lesson, the TI group made several changes to the original design of the lesson. In an early meeting, Todd began to question the actual content of the lesson, expressing a concern that the content of the lesson was weak and suggesting incorporating standard deviation into the lesson. We discussed, however, that the comparison of experimental and theoretical probability was the primary mathematical content embedded in the simulated data collection, to which Beth commented, “Those words went over my head.” Beth’s confusion actually helped convince Todd that the material contained in the lesson would be challenging yet comprehendible for College Algebra students.

This discussion also helped the group feel comfortable in making the first significant change in the lesson plan. They had become concerned with covering the material in the original lesson during the 50-minute College Algebra class period. Once they agreed that the primary focus of their lesson was the comparison of theoretical probability to experimental probability, the decision was made to save time by deleting the references to mean, median, and mode. Without the group discussion and interaction, it is unlikely that an individual member of the group would have been confident enough to make this pedagogical-content change before testing the lesson in the classroom.

The discussion of comparing theoretical to experimental probability continued further when they realized that no one knew the true theoretical probability of passing the test, using Nathan's technique. Everyone agreed that, while it was very unlikely that anyone would pass in the experimental situation, the theoretical probability was not zero. Todd decided to contact the statistics teacher on campus who explained to the group that the theoretical probability (calculated using the TI-84) was .00003 or .003%, thus expanding their content knowledge.

The use of technology in the lesson was also discussed. The group decided to follow the suggestion of the retrieved lesson plan and use TI-83 or TI-84 calculators, which were available in the department. The group needed to make a choice, however, for the teacher demonstration to be done using the TI-ViewScreen or TI-SmartView. During his task-based interview, Todd had discussed the differences between these two tools. He felt that the advantage to TI-SmartView was that the students could see the calculator screen, the actual calculator keypad, and a selection of smaller calculator windows allowing for multiple representations, but that many students might actually be distracted by that variety. He felt the advantage of the TI-

ViewScreen was that the students would see exactly what their calculator screen showed – no more, no less. The final group decision was to use TI-SmartView.

First modifications. Todd was the first to present the lesson using the group's lesson plan. After each member of the group watched the videotape of his lesson and completed the feedback forms, the group met to discuss changes to be made before Chloe's teaching of the lesson. Since the focus of my analysis is on the group and their reactions to the lesson, each presentation of the lesson will be discussed through analysis of the feedback forms and group discourse, rather than through my direct observation or fieldnotes from the individual lessons themselves. Fieldnotes will be used where necessary, however, to triangulate findings from the group's discussions.

The group member's feedback forms related to Todd's teaching of the lesson, although completed individually, contained a reoccurring theme; the connection between the technology and the mathematics content was weak. This surfaced in responses to questions 5 and 7 as follows.

> Question 5: Identify any pros or cons in using the technology to present the content of the lesson. How would this lesson be different (better or worse) if technology was not used?
>
> Chloe: The connection between the use of technology and content was not made.
>
> Question 7: Describe how the lesson accomplished (or did not accomplish) the overarching goal of the lesson.
>
> Chloe: I do not think that the overarching goal was reached in this lesson. The content somehow got lost in the technicalities. Although I believe in the original lesson plan the content was not well organized or made clear.
>
> Todd: It did not because the students [were] learning technology rather than using it to enrich their understanding of the probability.

Beth did not submit her feedback forms. As indicated in the biographical data, this was a difficult semester for her, and she fell behind in several assignments. She did, however, watch portions of the video and participate in the group discussions of the lesson. Teachee feedback forms add credence to the observation that the connection between the technology and the content-related objective of the lesson may not have been established. Of the six teachees, five commented that what they learned from the lesson was that they should not use the calculator to cheat on an exam while only one indicated learning about probability, the objective of the lesson.

Forming a stronger connection between content and the technology became a major topic of discussion at the next group meeting. Chloe proposed providing “a stronger introduction” by reminding the teachees, “What we are doing is finding the likelihood of Nathan passing the test after he had already made his random numbers . . . I think the point of the lesson is the probability part of it, not necessarily the random integer function.” Todd had included this same thought in his written response to question 8, “What changes would you suggest making when the lesson is presented again?” He responded, “[Give a] longer introduction of the background information.” During the group discussion, he added, “That is the only thing I wish we would have dealt with a little bit more, theoretical probability and empirical probability.” The group decided to expand their opening introduction with a short discussion of probability. They would then have the teachees read Nathan’s story and discuss simulating what Nathan did. They would refer back to this introduction at the conclusion of the lesson once the data had been collected and empirical probability had been determined.

One additional change in the lesson was based on a suggestion I made. The lesson, as retrieved, directed the teachees to enter the correct test answers into L1, then simulate Nathan's random number generation of his own test answers to be stored in L2, followed by a comparison of the two lists. I questioned whether the group thought it might clarify the overall process if the random test answers were generated and stored first, and then the correct answers entered, so that the comparison would simulate grading a test. Todd responded, “I just don’t know how much of a difference it really makes.” Chloe, on the other hand, responded, “I think it makes a huge difference in the way it goes.” She suggested that when presenting it to the teachees they should read about Nathan, and then immediately “generate answers like Nathan did.” They agreed to give that a try and discussed making modifications to the worksheet. Since it was retrieved from the web as a .pdf file, it could not easily be edited. The group discussed just telling the teachees what steps to do (out of order) and leaving the worksheet as it was. They discussed the option of cutting and pasting. The final consensus was that Beth would try to use the screen images and the key stroke icons from TI-SmartView to recreate the worksheet. Chloe, who would be teaching on Friday, asked if this could be ready by Wednesday, and Beth indicated that would not be a problem. The group's decision to modify the previously developed lesson plan suggests that they are developing knowledge of instructional strategies and representations for teaching specific topics with technology, as described by Niess (2005).

The group continued to discuss several other items, but returned to the issue of tying technology to the content once again when discussing changes to the worksheet. A transcription of the conversation follows.

Todd: I think it is real important to show the theoretical probability, just so they can have something to compare it to.

Chloe: Wait, we need something to create a connection. Like this is all fine, but have we really taught them – I don't know – I think it comes down to like, are we trying to teach them more technology or more probability? And there's got to be a way to do that evenly. And there's got to be a way to make the connection where it's meaningful.

Researcher: Well, what are you trying to teach them?

Silence….

Todd: Empirical probability. But the thing is we did nothing at all on the technology to get it, the actual empirical probability, besides simulating the answers. All the work on that true probability came from hand. That is the thing we are lacking on. If somehow we can link arriving at the empirical probability strictly by using technology, but that conflicts with our worksheet. The thing is we are not actually….

Researcher: What are you trying to teach them?

Todd: We are teaching them empirical probability.

Researcher: What does empirical probability mean?

Todd: The likelihood of getting something right through experiment.

Researcher: Through experiment. That's the key word – empirical probability is conducting an experiment….

Chloe: So what if we just went in and said, today we are gonna talk about empirical probability. And what is probability? Ok, let's talk about probability for a minute. And then add the word empirical. And then I tell them [or Beth tells them], empirical probability is finding the likelihood that something will happen by experimenting and the way we are gonna do this experiment is through our TI-83. And we are going to…

Beth: Now, in their math books instead of using the word empirical they use the word experimental…

Chloe: Either way…

Beth: They understand experimental. You can also say that some books use the word empirical – it means the same as experimental.

Chloe: That means you have introduced two words and they say you should introduce things two years before mastery.

Researcher: Like a word wall.

Chloe: So we have introduced two words to them that mean the same thing. So I think we just hit the nail on the head.

Researcher: I do too.

Todd: It's actually in our worksheet – experimental.

Researcher: Because what you are really doing with the technology is to simulate data collection; to simulate an experimental activity.

Chloe: And I knew there was a way; I knew it was a matter of telling them what we were doing to make the connection.

Researcher: And not necessarily telling them what you are doing, but focusing them …Let them make the connection…

Chloe: Right.

They decided to incorporate this into their expanded introduction and their modified worksheet. They seemed to be satisfied that by using both of the terms experimental and empirical probability to describe the collected data, then tying that to the theoretical probability, the goal of the lesson would be accomplished. By recognizing the importance of using specific vocabulary in the presentation of the mathematical content the preservice teachers demonstrated pedagogical content knowledge.

A second theme identified in the written feedback and discussed by the group was related to the pacing of the use of technology in the lesson. As Chloe indicated on her final feedback form, "There was also a significant amount of time spent helping individual students with calculator problems." Todd turned the group discussion in this direction when he asked, "Let's talk about the use of technology. How do you think that went?" Chloe reinforced her written feedback by indicating that she thought it went well, but that a lot of students needed individual help. She added that their proposed stronger introduction might help with this, and Beth added that the new sequencing in the worksheet might help also. Still thinking about specific problems he had with the technology during the lesson, Todd expressed concern that one of the steps that created problems for the teachees was the use of “2nd-enter, 2nd-enter” to repeat the generation of the random numbers. “The thing was, if they press more than what it said on the worksheet and then they try to press 2nd-enter, 2nd-enter, it might not show [the commands to generate the random numbers].” The group agreed that shifting from the use of 2nd-enter to actually retyping the commands to generate the random numbers might actually be less confusing. They agreed that Beth would incorporate that into her newly created worksheet by directing the teachees to “run the simulation again.” That the group's decision to replace specific commands related to the technological tool provides evidence of TPCK.

Chloe incorporated the changes into the group's lesson plan and used this modified plan along with Beth's modified handout to teach the second group of teachees. The TI group members then watched her video, completed written feedback forms, and met once again.

Second modifications. In their written feedback to the second teaching of the group lesson, both Chloe and Todd indicated that the changes made to their group lesson proved to be “good.” Todd indicated that “It was good to do a random sample then compare, as earlier we had the comparing example first,” but also stated that “we are closer but I feel that we did not leave the class with our students knowing a great deal of empirical probability through simulated exercises.” Chloe’s written feedback indicated, “I believe that the students understood probability and the overall activity better. I felt like the connection was made between the content and the technology.” While Beth did not complete her written feedback forms, she did express the same reactions to the lesson modifications verbally at the next group meeting.

The teachee feedback forms offer objective evidence related to the effectiveness of the changes. When asked what they derived from the course, three of the six responses indicated they learned something related to probability or technology, matching the objectives of the lesson. Two teachees indicated learning the importance of studying for a test, and one teachee left the question blank. This count is compared to only one teachee feedback related to probability in the first presentation of the lesson.

The effectiveness of the changes was the primary topic of discussion at the group meeting. Paraphrasing the discussion, Todd indicated that he felt the sequencing change in the lesson, doing the simulation first then entering the correct answers, made “a small improvement.” I asked what he based this on, and his response was, “There were less questions.” Fieldnotes from Chloe’s teaching support this statement. There was one teachee that struggled to keep up, but the majority of the group conducted their simulations and calculated their scores with much less confusion than the first group of teachees. Todd also pointed out that “one great thing I think that we did more than anything else on this worksheet, we took out that 2nd-enter thing. I think that helped a lot.”

The only additional changes the group discussed were related to fine-tuning their worksheet. This involved a few typographical errors and a few spacing changes, but no significant sequencing changes. Beth did express a concern that her audience, the EME class, might find the lesson trivial. The group reassured her that everyone would learn something from the lesson.

Todd shared an interesting observation with the group. He noticed that the TI-SmartView large screen display in Chloe’s lesson was the keystrokes, rather than the home screen as he had used. Chloe indicated that she had not intentionally set it to the keystrokes but decided to leave it so the students could see what she had pressed. While it did not seem to create a problem, and was not mentioned on any teachee feedback, we discussed that this might be a topic for further investigation at a later time. These small changes and observations indicate that the group is aware of the subtleties involved in teaching with technology.

Armed with the worksheet containing the final changes, Beth taught their group lesson for the third and final time to the EME class. With only minor changes incorporated into the lesson between the second and third teaching, the overall format of Beth's lesson closely followed that of Chloe's. With a different audience, however, a few interesting events occurred. Beth began the lesson by asking the members of the class, "Does anyone not have their graphing calculator?" The TI group had been prepared with extra calculators for every presentation of the lesson, but had not needed them in prior teachings since calculators were required for use every day in the College Algebra class. This was not a requirement in the technology class, however, and the TI group's preparation paid off – every member of the class borrowed a calculator. Once the calculators were distributed, Beth passed out the worksheet and began the lesson.

Beth had the EME students work with her, entering the commands on the worksheet and discussing their purpose. After completing the first simulation of Nathan's test responses, Beth instructed the class to "run through the simulation two more times." She pointed out that it would not be necessary to re-enter the "correct" answers, and instructed the class, "Just run the random integer again and do the sum again. Those are the only two parts you really have to repeat." As they worked through the second and third simulations, several members of the class made the comment, "I got the same answer all three times." Beth inquired, "You went back to [List] 3?" to which the student responded, "I went to [step 6 on the handout], and then I skipped back to the third number 1." The third number 1 was the summation of the numbers in L3. In following Beth's directions, the student had omitted the step where the calculator compared the newly generated list of random numbers to the correct answers. The numbers in her L3 never changed, resulting in "the same answer all three times." With limited experience in teaching with the graphing calculator, Beth did not immediately recognize the error, and it was not until watching the videotape of Beth's lesson that I recognized this error. Since there was no group meeting to discuss modifications following this third teaching of the group's lesson, the TI group never discussed this error. The repetitive cycle of the MLS process did provide, however, opportunities to develop additional insight into possible student errors, an important aspect of developing TPCK (Niess, 2005).

Beth brought closure to the lesson by compiling the results, which indicated that no one had passed the hypothetical exam, and asking the EME students to respond to the final questions on the handout, providing feedback on the lesson. Feedback from the members of the XL group, who were unfamiliar with the TI group's lesson, agreed that the handout was easy to follow, "Like a map," and that the technology made the lesson easier.

TPCK Changes in the TI Group

In maintaining focus on the research questions, the following sections address the evidence of changes in technology-related knowledge areas in the preservice teachers as they worked through the microteaching lesson study process. Applying the framework established by Mishra and Koehler (2006) and the coding scheme developed during the pilot study (Cavin, 2006a, 2006b) and modified for use in this research, I provide evidence of changes in technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge.

Technological content knowledge. The group gained technological content knowledge in the use of both the graphing calculator and TI-SmartView. The use of the random integer function, the test function, and the list-sum function on the graphing calculators represents technological content knowledge. Each of these functions was new to at least one member of the group.

In the process of working through the lesson with the group, additional technological tidbits were discussed. In a group meeting, Todd thanked Beth for showing him how to insert deleted lists, something that did not happen in their lesson presentations but is a quite common technological problem with the graphing calculator. In working with the statistics teacher to verify the theoretical probability of passing the test, Todd learned several of the statistical functions of the calculator. And when the process of clearing the lists at the beginning of the lesson proved to be time consuming, I showed the group how to clear all lists from the memory function, which Beth used in her teaching of the lesson. In discussing this command, Beth indicated that she knew of the command but did not think of using it here. These examples provide evidence that working as a group and discussing the lesson provided opportunities for the preservice teachers' technological knowledge to develop into technological content knowledge as they take advantage of what technological tools can do efficiently and well (TCX1).

Technological pedagogical knowledge. Determining an effective way to convey the use of the technology to the students involves technological pedagogical knowledge. This includes identifying productivity tools used to assist with management of student learning (TP4). In their modification of the worksheet, the TI group used word processing capabilities along with the TI-SmartView technology to construct an updated, more modern worksheet that provided the teachees with a visual image reflecting the actual process they would be using during the lesson. Use of this modified worksheet reduced distractions during the lesson caused by "scratch-outs" or out-dated images contained on the original version of the worksheet.

Technological pedagogical knowledge also includes knowledge of "the existence, components, and capabilities of various technologies as they are used in teaching and learning settings" (Mishra & Koehler, 2006, p. 1028). While not related to the specific content of probability, the group indicated an awareness of the "components and capabilities" of the graphing calculator in several instances. As Todd indicated during a group meeting, if the students did not follow the directions exactly, the 2nd-enter command did not work. Their shift to the use of re-entering specific commands rather than using the 2nd-enter option demonstrated an awareness of pedagogical strategies incorporating technology in an efficient manner.

They also discussed, early in the lesson planning, the original worksheet's use of scrolling down to an option then pressing enter, rather than pressing the number of the desired option. In particular, to select the random integer function, option 5, the worksheet indicated to "select option 5 and press enter." The intention of the worksheet was for the students to scroll down to option 5, and then press enter. When the students pressed 5 first, to select the option, the calculator advanced to the random integer screen, not requiring the use of the enter key. The group felt that most students would press 5 first, and that the direction on the worksheet would create confusion during the presentation of the lesson. On the original worksheet, they crossed out the enter command. While this is a small change, even minor reductions in confusion related to directions when incorporating technology into a lesson saves time.

Technological pedagogical content knowledge. TPCK involves an overlapping of technology, pedagogy, and content knowledge that incorporates the knowledge necessary for the integration of technology in teaching (Mishra & Koheler, 2006). Evidence of TPCK in the TI group is focused in two areas – using the technology to perform content-related functions, and pacing and sequencing the content-related technology functions to more effectively tie the technology to the lesson content.

While such functions of the calculator as using 2nd-enter and scroll-enter versus selecting a number are generic in nature and would apply when using the calculator in multiple content areas such as mathematics, science, or business, many of the functions selected by the TI Group were specifically related to the content they were presenting. Selecting the random integer function in place of having the teachees randomly complete a bubble-sheet (as discussed during an early group meeting) demonstrates a decision that takes advantage of what technology can do efficiently and well (TPC5). Although Todd, in his final survey, still indicated that it "could have been done by hand," the group decision to maintain the use of the calculator to run the simulation, then score and tally the number of correct answers, demonstrates an awareness of the potential of the technological tool. Their decision demonstrates knowledge necessary for the integration of technology in teaching – or TPCK.

The decision to use TI-SmartView rather the overhead view screen for the calculator is also evidence of TPCK (TPC4). As we often say in class, there is not necessarily a right or wrong answer. The choice to use either TI-SmartView or the TI-ViewScreen would have been appropriate. It is the decision-making criteria applied by the group that provides the evidence of TPCK. In their second group meeting, Todd and I discussed the options as follows.

Todd: Would you rather use TI-SmartView than the overhead projector?

Researcher: No, that is a decision you all need to make.

Todd: The reason I am saying this is because we talked about this the other day and I have been thinking about this. Especially with the functions they are gonna be using also. With the overhead presenter [sic] you don't see the actual calculator.

Researcher: That decision is entirely up to you. Talk with the group about it. Weigh the pros and cons. Certainly they both would work. As a group, decide which one you think would be the most effective for the lesson.

In their group conversations the TI group indicated that the strength of the view screen lies in the fact that what the teachee would see is the actual calculator screen, with very little distraction or confusion. The strength of TI-SmartView is that it allows the teachee to see the buttons as they are pressed along with either a keystroke history or the large image of the calculator screen. In presenting multiple images, however, TI-SmartView's more sophisticated presentation may also be more confusing and distracting. The group's final decision was that using TI-SmartView was the best choice for their lesson. Todd reflected on this decision in his final interview. When asked to describe the benefits of TI-SmartView he stated, "It's something like; you know how you said you can't be there with the students watching them. In a way you are, because all the students are looking. If all the students are looking at the board watching you do it, you are actually right there and they go verbatim along with you. So you can be 18 places at one time."

As a side note to this choice, I should share with the reader that TI-SmartView was very new to our campus at the time the research was conducted. So new, in fact, that the College Algebra teacher was conducting a small research project by using the TI-ViewScreen with one of her classes and TI-SmartView with the other. Her plans were to compare responses to the calculator-related problems on their exams to investigate the effectiveness of TI-SmartView. I did not realize that when Chloe presented her lesson to the 8am class, they had not seen TI-SmartView prior to her lesson. This was mentioned on the feedback form by one of the teachees. In response to the question, "what would you change if you were teaching this lesson?" one teachee responded, "I would have had the calculator on the overhead instead of on the computer. The computer one was hard to follow." The results of the comparison between TI-SmartView and the view screen will be interesting to investigate at a future time.

The group's decisions to change the pacing and sequencing of their technology-enhanced lesson also provide evidence of TPCK. The lesson they selected was based on an outline taken from TI.com, an established on-line resource for classroom lesson plans. To meet time constraints they made modifications to this lesson, deciding as a group what to leave in and what to take out. As they reflected on the first teaching of the lesson, they questioned the effectiveness of their modified lesson, stating in multiple instances that the technology and the mathematics seemed unconnected (TPC6). As discussed above, the group made the decision to change the sequencing of the lesson so that, as Chloe stated, "it flows better." Reflections on the second teaching indicated that the group felt the changes did enhance the effectiveness of the lesson, which was supported by teachee feedback. Both the pacing and sequencing changes were made by the group rather than by an individual as they discussed, presented, and reflected upon their group lesson. Without the group's interaction, repeated presentation, and reflection it is unlikely that the lesson plan would have been modified as extensively, allowing the lesson to reach its final level of effectiveness, providing opportunities for the development of TPCK (TPC2).

The Case of the XL Group.

Like the TI group, the XL group began with an internet search. The following sections describe the procedures used in selecting, developing, presenting, and modifying their MLS group lesson, with an emphasis on technological, pedagogical, and content-related decisions made by the group.

Selecting a lesson. As part of the assignments for their course, the preservice teachers were required to compile a "table of favorites" which included links to some of their favorite on-line content lessons. Scott shared one of his "internet favorites" with his group, a lesson related to the use of credit cards in making purchases, as a possible source for their group lesson. The XL group explored the lesson, "I want a credit card, or do I" (Harrigan, 2000) at http://score.kings.k12.ca.us/lessons/crcard.htm and liked the fact that, as Margie commented, it was "more real to life math."

In the original lesson plan, the students pretended to borrow $1000.00 on a credit card, and to make hypothetical payments for one year, adding the interest and other charges and deducting the payment to determine the unpaid balance. They would then analyze the total payments to determine the amount that went to principle and the amount that went to interest. Students would then make a pie chart showing the percentage of principle and interest, and discuss the pros and cons of borrowing money on a credit card. While it is possible that the intention of the original plan was to use technology to create the pie chart, there was no specific mention of technology in the original lesson plan. Since this was a requirement for the XL group's lesson, inclusion of technology became the first modification discussed by the group. I encouraged them to consider their goals for the lesson and then to select the technology that would best accommodate those goals.

After much discussion, John suggested the use of TI-Interactive. In his proposal, the teachees would enter into the list function of TI-Interactive the monthly unpaid balance due on a credit card with a predetermined principle, interest rate, and monthly payment amount. The data would then be plotted, and the teachees would investigate what type of function was represented by the graph, followed by the calculation of the regression equation that would best model the data. This concept was very similar to several of the modeled lessons completed earlier in the course. The group spent the remainder of the class period, approximately one hour, discussing the possible use of TI-Interactive in their lesson, summarized as follows.

Scott: So, that's how you would do that. We did that basically in class already.

John: And then we could ask them questions kind of like we had on the [excel lesson we did on interest]. Like what would happen if the interest went down or the interest went up.

Scott: So are we saying we are wanting [sic] to do this lesson?

Margie: It looks fine.

John: It looks fine to me.

Scott: And the whole purpose of lesson study from what I gathered is that it is kind of like an all-encompassing lesson that sums up a whole bunch of points, right?

Margie: Ok.

Scott: So what we would want to do is find out what are we gonna – how are we gonna corral all this information into a . . .

John: To a lesson plan.

Scott: Yeah, to the lesson plan.

Pre-teaching lesson development. The XL group continued working on a lesson plan using TI-Interactive for the remainder of the two-hour class (Tuesday) and all of the next one-hour class period (Thursday). They discussed several options for exploring the effects of borrowing money on a credit card, such as comparing two credit cards with different interest rates, different minimum payment amounts, or comparing a loan from a bank to a credit card. In each situation the group remained committed to the use of TI-Interactive as the technological tool that would best facilitate the comparison, selecting an educational software tool for instructional purposes in mathematics (TPC4).

As they worked on developing their lesson, the completion of the lesson plan form (Appendix G) used in the MLS process (Lewis, 2002) proved to be a difficult task for the XL group. As they debated what to enter in each column of the form, their discussion oscillated back and forth between the detail of the lesson and the overall "big picture." Scott proposed identifying the overarching goal of their lesson as "the relationship between the different rates of interest and the graphs." Margie's concerns were expressed in the questions, "What exactly are we gonna do in the lesson? Are we gonna have one interest rate? Different interest rates?" John added, "How are we going to start this?. . . [W]e will have to introduce them to TI [Interactive]." As evidenced by the disconnected statements, the XL group was struggling to solidify the goals, objectives, and content for their group lesson.

This was further complicated by the realization that the teachees would probably not be familiar with TI-Interactive. A discussion followed related to the merits of introducing the technology first and then beginning the lesson, or beginning the lesson and introducing the technology, as Scott described it, "in line." Scott felt that, "if we try to give them a separate little instruction on [TI-Interactive], then we are gonna have to start back over and then start our lesson plan which is gonna take 5 or 10 minutes out of our lesson plan." He believed the technology could be introduced, as needed, within the lesson. Discussions such as these provided opportunities for the preservice teachers to develop technology-related learning activities related to the content area (TPC1).

As the group continued to work on the completion of the lesson plan form they discussed "expected student reactions" and "teacher responses." One concern expressed was that the teachees would unintentionally close TI-Interactive and lose their work. The group decided to have the teachees save their documents after each significant step. The group continued to discuss procedures for logging on, introducing the project, importing data, and entering equations, along with options for assessment. Even though they were struggling with the actual lesson plan format, these observations indicate that the form was serving a purpose. In the process of completing the lesson plan, the preservice teachers worked through several hypothetical scenarios that helped in the decision-making process related to the use of their selected technological tool.

Although they were making some progress on the lesson plan, they all agreed they needed individual time to become more familiar with the content and the technology in order to better facilitate group decisions and lesson development. Scott suggested each member of the group go home and think it over. They agreed to do just that and to meet again the following Monday.

In the first few minutes of their next meeting (Monday), the group began discussing the use of an Excel spreadsheet to explore the effects of buying on credit. There was no discussion as to how or why the change was made from TI-Interactive to Excel as the technological tool of choice. I was surprised, and asked for clarification. Margie indicated that, when they went home to continue working on the project individually, they all became concerned. They had agreed, via email, that no one in the group felt comfortable enough with TI-Interactive to use it in teaching the lesson. Since none of them had TI-Interactive on their home computers, no one could practice the lesson to develop expertise. They were also concerned that the teachees would not be familiar with TI-Interactive, but agreed that those same students would be familiar with Excel. John confirmed Margie's description of the group's weekend communications. (Scott was not present at this meeting.) In making the decision to change the technological tool based on their own comfort level, the XL group confirmed that teacher comfort levels with technology is a factor in the selection of a technological teaching tool (Kersaint et al., 2003). In considering the comfort level of the teachees, however, the XL group expanded the comfort level factor beyond that of the teacher comfort level, to include the perceived comfort level of the student.

Beyond the change in the selected technological tool, the XL group had actually made several modifications to the original lesson outline during their weekend email communications. The group shifted the focus from borrowing money on the credit card to purchasing a laptop computer using a credit card, and established initial values for the variables contained in the calculations. The charge for the laptop was set at $1000, the APR for the interest was set at 9.9%, and the monthly payment set at $25. Their plan was to allow the teachees to investigate the effects of the interest rate and monthly payment on a credit card purchase by entering the data into an Excel spreadsheet, and using the functions of the spreadsheet to calculate the unpaid balances. The title of the lesson handout, "Worth it or not," provided insight into the primary goal of their lesson.

Using the new group lesson outline, Margie had worked on a sample spreadsheet and class handout over the weekend so that the group would have a starting place at their Monday meeting. She emailed it to Scott and John so that the group would be ready to begin discussion and modification of the lesson when they met. John opened the Monday meeting by telling Margie, "I followed your handout and it worked pretty good . . . Your detail is great." They worked on fine-tuning the spreadsheet, handout, and lesson plan as they discussed the pacing of the lesson. John indicated that it took him only 15 minutes to work through the lesson, but they were concerned about how much their teachees would know about using Excel. They discussed the amount of class time that might be needed to teach the technology, reflecting the same concern about pacing exhibited by the TI group.

In light of the time constraints, they discussed whether they should still try to graph the data as proposed in their first lesson plan draft, in order to identify an algebraic representation for the relationship between the elapsed time and the unpaid balance.

> John: So do we want to go with the graphing part after this [because the lesson is too short]?
>
> Margie: I don't know, what do you think?
>
> John: Do you think we will have time?
>
> Margie: See, that is why I am concerned. I don't really know that we will have time.
>
> John: What if we planned like we would have time and then, after the first lesson . . .
>
> Margie: After we teach the lesson . . .
>
> John: Right, after the first lesson we will know how much time it took. So we can plan to go further but, if Scott [who was planning to teach first] runs out of time, we can cut it off there.

This recognition that they have an opportunity to evaluate and modify the lesson after the first teaching reflected an awareness of the power of the MLS process.

The group discussed graphing the data within the Excel spreadsheet but had difficulties generating a regression line. They elected to copy and paste the data into TI-Interactive, graph the data, and create a regression equation. The group's decision was, that if time allowed, they would show the graph of the data to the teachees, discuss the type of regression line that would best fit the data, and then demonstrate possible regression equations in TI-Interactive. The XL group created an initial sample of a linear regression line to help the teachees realize that, although the data plot appeared somewhat linear, the relationship was not truly linear. While a discussion of a best-fit regression equation was never included in the actual teaching sessions due to time constraints, the group discussion related to plans for possible inclusion provided opportunities for group members to explore the potential of the technological tool to create a visual image of a mathematical concept.

In finalizing their plan for the first teaching of the group lesson, some minor modifications to the handout, spreadsheet, and the formal lesson plan (Appendix J) were made. Cell borders were added to the spreadsheet, labels were changed to ensure consistency between the handout and the spreadsheet, and several "what if" questions were added to the end of the handout. These included such questions as, "what if the monthly payment doubled," or, "what if the interest rate changed." The spreadsheet had been designed using formulas, so these questions could be explored by simply changing the value entered in the initial cells, and observing the resulting changes immediately recalculated by the formulas. To test the handout, Margie had her step-mom work through the lesson handout step-by-step, and watched for potential problems. She found none. We discussed the logistics for teaching the lesson. The XL group would teach in the technology lab on Monday, March 5th.

First modifications. John, the first to teach the lesson, began EXACTLY as indicated in the lesson plan. Students logged on, were given the handout with directions, and asked to open the Excel document and save it to their own folders. Then, as indicated in the lesson plan, students were asked to "begin the lesson according to the handout." While John did demonstrate entry of the three basic data values, the beginning balance, the interest rate, and the monthly payment, he did not demonstrate entry of any formulas. He directed the teachees to work through the handout as he circulated, offering individual assistance as needed. The lesson plan predicted that "students may have trouble creating the correct formulas and placing them in the correct spots." This turned out to be true, requiring more time than anticipated for the teachees to enter the formulas and calculate the unpaid balances at the end of each month. As a result, class time ran out before the teachees were able to investigate any of the “what if” scenarios included in the lesson plan.

When time ran out, John asked the teachees to complete only two of the five feedback questions at the end of the lesson handout. In response to “was the technology you used in this lesson beneficial,” feedback ranged from, “yes, after I got the hang of it all it was really easy to use,” to, “no, because it was too hard to understand and it kept messing up.” In response to the second question, “if you could change anything about this lesson, what would it be?” the feedback was almost unanimous. As one teachee stated, she would recommend “explaining the steps orally instead of [the teachees] having just to depend on the handout.” Scott and Margie concurred. In their individual feedback forms, Scott stated that he would “spend a little more time covering the handout with the students,” and Margie said “it would be a good idea to periodically make sure that all of the students have gotten to a certain place.”

John also realized that the pedagogical strategy used in the lesson, letting the teachees follow the handout and providing assistance on an individual basis, was not successful, but with a little different outlook. On his lesson feedback form he stated, “The lesson strategy used was to follow directions and do it yourself. This method did not seem to work because the students wanted to jump right in without reading the directions and the students were completely Excel illiterate.” It is interesting that the students suggested John needed to explain it more, yet John indicated that the students needed to read the directions more thoroughly, each suggesting that the “problem” was not their own. While the intent was to “engage” the students in learning, the do-it-yourself strategy of following written directions did not appear to be effective.

At their meeting to discuss the videotape of the lesson, the written directions became a primary topic of discussion. Scott indicated that, as he watched the videotape, he saw the teachees looking at their handouts, then at their screens, then back to the handouts, then back to the screens. To Scott, this indicated they were reading the directions. John agreed that the teachees “looked” at the directions, but indicated they did not “read” the directions. Everyone agreed, however, that the teachees were not “following” the directions. Scott felt that the length of each step on the handout might have been overpowering, and recommended that each step be made a bulleted item rather than a descriptive paragraph. In future group discussions, these written directions resurfaced as a topic of concern.

A second, and perhaps more critical, topic of discussion was related to the actual spreadsheet itself. It had been coded so that when a correct value was entered into selected cells, the cells would turn green as a motivational factor, encouraging the teachees to continue working. Scott felt that if the directions indicated the cells would turn green when correct values were entered, then every cell should turn green when correct values were entered. He felt they were "building expectations just like Pavlov did with his dogs" and that any cell not turning green could be construed as an incorrect entry, discouraging the teachees from continuing. Margie and John had made attempts at coding every cell, but ran in to "technical difficulties." Any time the auto-fill function was used to complete a column of data, the formatting for the copied cell was applied to the entire column. This resulted in some cells turning green while not containing any data and some cells not turning green at all. They elected to have specific key cells turn green as designated rewards, and indicated these cells in the handout. They did not, however, indicate the cells that would not turn green. Scott agreed to work on the coding for the final teaching, but for the second teaching of the lesson, which was only a few days away, the group agreed to modify the handout to emphasize that only certain cells would turn green.

Additional suggestions made by the group included encouraging the teachees to work together, providing a little bit more introduction to the lesson prior to turning the students loose to work from the handout, and inserting stop points in case time ran out. The changes made to the lesson plan and handout between the first and second teachings of the group lesson were summarized by Margie as follows:

> We decided that a few key points needed to be addressed at the beginning of the class, so we added them to the introduction. After the first teaching, we decided that we needed to periodically stop and make sure that the students understood what was going on. After the first teaching, we also realized that the students might not get done with the assignment so made sure to note what questions the students would need to answer if time ran short. It was also obvious that the third part of the lesson was not likely to be reached, so we [identified this section as an extension]. We also changed the time frames we had given to each part of the lesson because it was obvious that they were off. As far as the handout is concerned, we went through and noted the cells that would not turn green.

Second modifications. Margie was the teacher for the second teaching of the group lesson. As planned, she did provide more up-front introduction, including comments about both the content and the technology. She explained that they would be investigating the effect of interest on making credit card payments, and emphasized the importance of using the equal sign and the F4 command in the Excel formulas. She also summarized the issue of the cells turning green and promised the teachees that "everything they would need could be found on the handout," emphasizing the importance of reading the directions.

Margie did not, however, incorporate all the changes to the lesson plan into her teaching. While she did work the first few steps of the handout with the group, she stopped short of demonstrating the entry of any formulas. Before she turned them loose, she did encourage them to help each other, emphasizing that it was "O.K. to talk." She did not, however, "periodically stop and make sure that everyone [understood] how to do the lesson, using the projector for demonstration." The college algebra teacher, observing Margie's teaching, made note of this in her written feedback with the statement, "[She] probably needed to go to the [teacher computer station] more frequently to direct the class. Students not being individually helped were not able to continue very far on their own." When asked in her final interview if this was a conscious decision, Margie replied, "No, I think it was just the way it worked out. I intended to stop more."

The changes Margie made in the teaching of her group lesson did facilitate the time factor, allowing her teachees to discuss the questions on the handout related to the summary of the data and to compare the cost of buying on credit to the cost of a cash purchase. They still did not have time to investigate the "what if" questions in the extension of the lesson. Teachee written feedback on Margie's lesson indicated that the technology used in the lesson was beneficial. Teachee comments included, "It eliminated a lot of work out of the math," that it, "was useful for getting organized," and, "it helped me learn interest rates on credit cards." When asked about what they would change in the lesson, however, nearly every teachee indicated the need for clearer directions with more verbal and visual instructions. After watching the videotape of Margie's lesson, the XL group met once again for their second round of modifications.

Discussion during their next group meeting was, once again, focused on the cells turning green for correctly entered data. Scott had written a visual basic macro to accomplish this goal to be used in the third teaching of the lesson, and had sent the modified spreadsheet to the others in the group. When they tried to run it, however, the macro did not work. After much discussion they realized that the security settings for the macro were too restrictive, and steps were added to the lesson handout providing instruction to the teachees on how to adjust the security settings. Scott acknowledged the importance of the group evaluation of the changes to the lesson in his final project survey. In response to the question statement "Feedback from my group members helped me understand the strengths and weakness in our lesson and areas for improvement," Scott indicated he "agreed," explaining that "Others see some things I can't. This is one of the best ways to improve. One example is feedback about the [spreadsheet] not working properly." Sending the spreadsheet to his group for their evaluation allowed Scott to prepare for a technical difficulty he had not predicted.

The group also discussed the teachee feedback, which requested more verbal and visual instruction. Scott proposed accommodating this by providing more teacher direction in the final presentation of the lesson. Scott summarized the changes made to the group lesson between the second and third presentation as follows.

> To summarize what my goals are, first I hope to improve the spreadsheet we use to teach the lesson, make it more intuitive to use. Next, my plans for instruction will change from roaming to being more at the podium, offering instruction by example. I will also update the handout to reflect any changes in the use of technology for this lesson. Finally, the changes made should help move the lesson along so all questions may be answered at the end of the lesson.

Scott presented the group lesson to the EME class, using the modified spreadsheet and handout. In relation to the modifications, two interesting events occurred. When one teachee was entering her data, she received an error message indicating a visual basic error. None of the others in the class had this problem, and, fortunately, it did not prevent her from continuing with the lesson. It did, however, provide an opportunity for Scott to gain experience in dealing with the unpredictable nature of teaching with technology.

The second event occurred when the two members of Scott's group, John and Margie, knowing what the lesson entailed, worked ahead of the class. I felt these students should work with Scott rather than ahead, participating in the lesson as a student rather than a group member. I asked them to delete their spreadsheet entries to "catch up" with the group. When they did, their spreadsheet cells remained green, even without the correct data entered. This, once again, did not prevent their continuing the lesson, but did distract from the purpose of the green cells – rewarding correctly entered data. While the reason for the cells remaining green was never investigated, it did provide food for thought for future attempts at including visual basic coding in a lesson activity.

TPCK Changes in the XL Group

In the above sections I provided a chronological summary of the events that occurred in relation to the development of the XL group lesson. These events are centered on three primary ideas: the importance of the written directions in a student-centered learning environment, the necessity for some amount of teacher direction, and the motivational importance of the cells turning green. These ideas, among others, are addressed in the following sections as the events are examined for evidence of the development of the various forms of technology-related knowledge: technological content knowledge, technological pedagogical knowledge, and technological pedagogical content knowledge.

Technological content knowledge. Establishing evidence for the existence of technological content knowledge is a little more complicated for the XL group than the TI group, since Margie is majoring in secondary science while John and Scott are majoring in secondary mathematics. In her reply to the final survey Margie actually indicated, “The lesson was not done in my content area. I didn’t learn anything about my content area while developing the lesson.” She added in a later statement, however, that when presenting a technology-enhanced lesson, “Sometimes technology does strange things, and you can’t explain it.” When questioned about what she meant, Margie explained that this comment referred to the variation among computers she had experienced during her teaching of the group’s lesson. When entering the interest rate, all teachees entered a value of .099. Several computers displayed .099, and several displayed 9.9%. Margie quickly announced to the class that the format used in the display would not affect the calculations within the formulas. Her ability to quickly and efficiently deal with this discrepancy indicated awareness of mathematical content, and of the quirks relating that content with technology (TCK2).

TCK is also evident in one group session where Margie and John were working to fine-tune the group spreadsheet. They considered the possibility of including graphs of the data and wanted to determine the time required to reduce the unpaid balance to zero. John showed Margie how he used TI-Interactive by calculating the regression line for the data and finding the zero of the function. Margie showed John how she auto-filled the Excel spreadsheet until the balance was negative (it never reached an exact zero value). By sharing their technology-enhanced solution techniques, these two preservice teachers facilitated the development of TCK in each other.

Technological pedagogical knowledge. The evidence of TPK is centered on two pedagogical issues; the use of technology as a motivational tool and the strategies used in a student-centered learning environment. Perhaps influenced by a modeled lesson they participated in earlier in the course (graphing patterns), the XL group included coding to make cells turn green as a motivational strategy from the start of their lesson. All members of the group agreed that green was the appropriate color, since, as Margie stated, "green means go." They all agreed that the motivation was important. John summed this up in his final interview. When asked if it was important that the cells turn green he stated, "Yes. It helps you also to know you are doing it right. I don't like myself to go and start something I don't know what I'm doing and then try to push my way through and not know if it's right or not. If I see that it's right I'm gonna keep pushing. But if I'm halfway down and I don't know if I'm right or not, I'm just gonna finish it out and not care."

There was some disagreement, however, as to whether it was important for all the cells to turn green (as they did in the final presentation), or if a few key cells would suffice for motivational purposes (as used in the first two presentations). In their final interviews, I asked the members of the XL group if, after watching the videotapes of the two different designs, they felt there was any significance to all cells turning green. In her reply, Margie still believed it was important for some cells to turn green, but not necessary for all the cells to turn green. John stated that in comparing Margie's and Scott's presentations, where some cells turned green and all cells turned green respectively, their effectiveness was about the same. He felt that their two lessons were "almost identical." Scott, however, maintained his conviction that all the cells should turn green if they are to serve as a motivational factor as indicated in the following quote:

> So once it turns green it lets them know Kudos, you got it right. And they'll proceed. But if they are used to that, you have to specifically state that this is the only cell that is gonna turn green. 'Cause they are gonna type in and if they don't know, and I've seen enough, and I've done it enough when I was younger myself – whenever I get used to a pattern and then it doesn't happen again, I will get stuck even though I have the right

answer trying to make it turn green. I just felt that it would ease things along and take the tension off the students, and they will get used to it. And if it's a set pattern that is supposed to happen, continue the pattern; don't yank it out from under them. They will get really confused.

While either outlook may be "right," what is important is that, in working through the MLS process, the members of the XL group were exposed to an outlook that was different from their own. They had an opportunity to observe a theory in practice, defend their own theory, and make a judgment related to effectiveness of the various theories. Whether the motivation was offered continuously or on a limited level, the technology was used in every case as a tool for motivational purposes (TP2).

The student-centered learning concept played a large role in the XL group lesson. When asked in their final interviews for their definition of student-centered learning, the group consensus was that the students are the center of everything, attention is on the students, and the students are learning. The teacher is not just "up there lecturing." When asked if there should be no lecture, Margie added, "It can be a little bit of lecture. Just not like telling them so they can spit it back out at you." It was perhaps their common belief that student-centered learning should involve minimal lecturing that prompted the preparation of the comprehensive handout to be used as a learning tool. The opening of the first version of the group lesson plan, in fact, simply indicated that the students would begin the lesson from the handout. They quickly realized this was not an effective technique in this context. This realization, facilitated through observation of the first lesson, provides evidence that technological pedagogical knowledge developed as the preservice teachers worked through the MLS process of reflection and modification.

One change made by the group in response to their observations was to modify the lesson handout. They inserted a blank space between each line item and, where possible, reduced the number of words in each step. In addition, tied to the green cell issue, they stated specifically which cells would not turn green. The group felt these changes would make the directions easier to follow, enhancing their concept of a student-centered learning environment (TP5).

Additional changes involved the amount of, according to Scott, "podium time," which was implemented in two ways. First, the group increased the opening of the lesson to include an introduction to the items that were difficult for the teachees in the first group to master. This included an introduction to the F4 function, the use of the equal sign, and encouragement to work together in small groups. Second, the XL group made a decision to stop at various points throughout the lesson to pull the teachees together, check for comprehension, and answer any questions the teachees had up to that point. As it turned out, however, neither of the second nor third presentations actually contained the stop points. When questioned about this in their final interviews, both Margie and Scott indicated that was unintentional. Margie indicated, “I think it was just the way it worked out. I intended to stop more.” When asked if he intentionally decided not to work with the class, Scott replied “No. It was more of an [adaptation].” Discussed further in the following sections, this provides evidence that beliefs toward student-centered learning and the internal concept of what student-centered learning involves can have an impact on actual teaching performance when using a technological tool in the lesson. The fact, however, that the group planned for the use of up-front introduction to difficult aspects of the lesson and stop-points to check for comprehension along the way provides evidence of TPK in the group members.

Technological pedagogical content knowledge. The original plan for the XL group lesson included the use of TI-Interactive. The final plan used Excel. The decisions made by the group to select and utilize educational software tools for instructional purposes in mathematics (TPC4) provide evidence of TPCK. This decision was influenced by multiple factors.

John pointed out, “We decided first upon the lesson that we wanted and the material that we wanted the students to get out of the lesson. Then, we considered the best way to present the information in a way that [would] be easy for the students to understand.” The objectives of the content lesson influenced the technological tool selected for the lesson.

Scott expanded on the influence of the lesson objectives when he described his attempts as using TI- Interactive.

> So my first reaction was to use TI-Interactive and do the lesson before they even started trying to work on it. That afternoon I went ahead to try to do that. And I noticed that you can’t expand a row or column by doing the [fill] in TI-Interactive. So that immediately trashed all the work that I did.

Even though he had invested time in TI-Interactive, the capability of Excel to meet the objectives of the lesson made it more attractive to Scott.

Scott and Margie shared additional factors that influenced the choice of Excel rather than TI-Interactive. Scott stated, "The unfamiliarity with TI-Interactive prompted us not to use it. It was difficult to get a table that [could] be updated dynamically. We chose Excel because of its ease of use." Margie confirmed this in her final interview when she stated that their experience in working with Excel allowed them to make the Excel spreadsheet more interactive, enhancing the student-centered learning environment. While either technological tool may have worked to present this lesson content, the familiarity with Excel and the ease with which the Excel-based activity could be made interactive and dynamic made it more appealing to the XL group. The conscious decision to use Excel over TI-Interactive provides evidence of a form of selecting mathematical tasks that take advantage of what technology can do efficiently and well (TPC5) and utilizing educational software tools for instructional purposes in mathematics (TPC2).

One section of the XL group lesson that was not fully developed, due primarily to time constraints, was the last section containing the "what if" questions. Many of the lessons modeled throughout the EME course contained speculative questions at the end to encourage the students to think about the same concept under different conditions. The XL group planned to incorporate that concept into their lesson by asking the teachees such questions as, "what would happen if the monthly payment doubled, or the interest rate changed, or the principle amount charged was different?" The structure of the spreadsheet was such the teachees would have been able to investigate these questions by simply making changes to the original values, allowing the formulas entered into Excel to calculate the effects of the changes. Due to the limited class time, group members often rushed through this portion of the lesson, or did not have time to cover it at all. Their joint decision to include it in the lesson plan, however, provided evidence that the group was considering the use of technology to expand student's mathematical thinking abilities (TPC2) and creating mathematical tasks that take advantage of what technology can do efficiently and well (TPC5).

Across-Group TPCK Changes

Several factors played a guiding role in comparing data across the two groups. The first factor was related to the variation between the two groups. Their lesson topic and technological tool selected were different. Their group dynamics were different. Their personalities were different, and their prior backgrounds were different. The second guiding factor in control was that I, as the teacher and the researcher and an experienced educator, did not want to impose my concept of what is “right” or “good” into the examination of the data. As such, I made every effort to compare the two cases with an open mind when coding the data and attempting to identify evidence of TPCK that appeared across cases.

The resources for this portion of the analysis included not only the group discussions, but also the individual final surveys and final interviews, as compared to the preliminary data and task-based interviews for the six individual participants. As a theme began to emerge in the data for one individual, it was not considered for inclusion here unless it could be triangulated by appearing in relation to at least one member in each group and for a minimum of three individual members. Once a code, or set of codes, was established as an emergent theme, the remaining data were re-examined for additional evidence of the credibility of the theme. In the process of coding, re-examining, and categorizing, the following themes emerged.

As the class worked through the first part of the course, participating in lessons that I modeled in relation to teaching with technology, we often discussed their role as learners in a modeled lesson versus their role as future classroom teachers of those lessons. In analyzing the data collected, these roles became the foundation for two emergent themes related to across-group changes in TPCK – preservice teachers' views on learning with technology and preservice teachers views on teaching with technology. These themes will be discussed in the following sections.

Preservice Teachers Views on Learning with Technology

This theme, related to the participants’ views on learning with technology, can be broken down into two categories: their view of what constitutes mathematics, and their beliefs in the interrelationship between technology and mathematics (which comes first). These themes are explored in the following sections.

What constitutes mathematics? Early in the MLS process, preservice teachers’ comments indicated that their definition of mathematics consisted primarily of arithmetic calculations, and that the technology used in mathematics lessons often helps "do the math faster," implying that technology helps do the arithmetic computations faster. As the members of each group worked through the MLS process, discussing the mathematics associated with their group's lesson, the preservice teachers' definitions of mathematics appeared to develop into a more broad scope, including not only the computation but also the formulation of ideas and concepts related to their lessons' objectives. Evidence of this development is provided in the following paragraphs.

The computational view of mathematics can be seen in the TI group's feedback early in the MLS process. Following the first presentation of their lesson, Todd indicated that "we actually did nothing on the calculator itself that actually dealt with probability itself. Because all our probability math was done by hand." He was referring to the actual computation of the probability of passing the test using randomly generated answers, which turned out to be 0 out of 18, or zero. Since the teachees did not "calculate" any specific empirical probabilities on the calculator, he felt they did not "do math." Chloe reflected a similar belief in her task-based interview. Developing an Excel spreadsheet to solve the problem related to the sale of tickets for a chili supper, she was asked how the technology enriched the mathematical understanding of the students, if at all. She stated, "Mathematically, I am just not sure it does because you weren't doing it with paper and pencil, and the math part is really being done for you." While she did go on to state that the process of setting up the spreadsheet was an important part of the task, the actual calculations were referred to as "the math." Beth's emphasis on computational mathematics will be discussed further in the following section as it surfaced in her statements related to doing the mathematics with paper and pencil first, the topic of the next section.

This early emphasis on computational mathematics appeared in data collected from members of the XL group as well. Following the first presentation of their lesson, when asked how the technology enhanced their lesson, all three members of the group focused on the fact that the technology assisted with the arithmetical computations. Margie replied, "Excel was used in this lesson to help the students see whether or not they were entering the correct information. It was also used to do the math for the students." John stated that "The technology presented the material in a quick and orderly fashion, and did most of the math for you." Scott reinforced the thought that the technology "does the math faster" with his comment, "If technology was not used, this lesson [might] take days to complete. Furthermore, student interest would dwindle as they got bored from toiling over the same data again and again." In each case, the preservice teacher referred to mathematics as the process of calculating rather than the overall concept of credit card interest. When they thought of the technology enhancing the lesson, they thought of the quickness of the calculations. John did include the "orderly fashion" as a plus, but still suggested that the technology did the mathematics for the teachees, rather than considering entering the formulas and the connections made between the interest rate and the unpaid balance as part of “the math.”

Before providing evidence of the transition that occurred in the preservice teachers' thinking about mathematics during the MLS process, let me take a moment to briefly review literature related to types of mathematical knowledge. Skemp (1978, 1987) addresses the issue of computational mathematics with his distinction between instrumental and relational understanding. Instrumental understanding represents knowledge of rules and procedures and relational understanding represents a more broad knowledge of why the rules and procedures work as they do. Skemp states that relational understanding is different from instrumental in many ways. With relational understanding, "the means become independent of the particular ends to be reached thereby," and that "building up a schema within a given area of knowledge becomes an intrinsically satisfying goal in itself" (Skemp, 1978, p. 26).

Hiebert and Lefevre (1986) offer a similar distinction between procedural knowledge and conceptual knowledge. Procedural knowledge is based on rules, algorithms, and symbolic representation, and is necessary for mathematical computation. Conceptual knowledge is characterized as knowledge that is based on relationships between various concepts and develops as students are provided opportunities to link new material to existing memory or to connect previously unconnected concepts already stored in memory. Forming relationships between the two types of knowledge is important to the development of a rich understanding of mathematics. While performing arithmetic calculations should be considered a part of the mathematics, it should not be the primary focus.

Expanding this statement to include technology, using technology to speed up arithmetic calculations should certainly be considered a part of the mathematics, but should not be the primary focus. Yet, it was the primary focus for the preservice teachers, early in the MLS process. Data collected toward the end of the research project indicated that the preservice teachers' outlooks on the definition of "the math" expanded. They began to include in their concept of "the math" the procedures used in simulating responses to a multiple choice exam and the exploration of the effect of the monthly payment on the amount of credit card interest charged. The following data provide evidence that the preservice teachers developed an awareness of relational understanding and conceptual mathematical knowledge, even though these topics were never formally discussed during the course.

The final interview protocol for the research project contained two sections. The first section contained standard questions asked of all participants. The second section contained specific questions for each individual participant designed to clarify responses on the final feedback survey submitted by that individual. In many cases, the use of technology to “do the math” was one item to be clarified. That clarification is given below for Margie, Scott, John, and Chloe, and provides evidence of a broader definition of mathematics than held early in the MLS process. Data related to Todd will be addressed later in this section, and Beth's feedback will be discussed in the following section. When the preservice teachers were asked to clarify the statements that the technology was used to "do the math," they replied as follows:

> Margie: [Yes,] the technology was used to do the math faster. It did the addition, subtraction, multiplication, and division. But the questions at the end (of the lesson) allowed them to apply what the technology did . . . We were trying to get them to see how the interest rate affected how much money was borrowed versus how much money was paid back, and different monthly payments. But some of the students were too focused on what needed to go in there; they weren’t seeing the big picture. They were more focused on this cell and this cell and this cell. That’s what we use. They were not focused on what those cells meant, what they represented.
>
> Scott: If it is just a general statement saying that the [technology] is computing everything for you – yeah – I will agree with that [statement]. But if you don’t know where to put the numbers you are not gonna understand the math. I would say it does more – it computes things but it organizes things in a fashion where you can clearly think about what’s going on.
>
> John: What I meant was, the students didn’t have to do any of the calculations. All they had to do is put in the formula and the Excel did the math for them. It did all the multiplication, all the transferring of data, everything.
>
> Researcher: So, do you think the students ended up doing any math?
>
> John: They did math in finding the formulas, or seeing the formula in the sheet and putting it in. That’s math. But as far as, um, multiplying, as far as the functions of math, they didn’t do any multiplying or adding or dividing or anything like that.
>
> Researcher: Do you think math is just add, subtract, multiply or divide?

John: No, its … writing functions IS math. Definitely. And typing numbers is math. Reading numbers is math as far as that goes.

Researcher: What about when they were done with all the formulas?

John: If you took it the next step, yeah they would be doing math. The next step was to extend it over time until you ran it out to zero, the balance, which would have been four years later. So, yeah.

Chloe: The calculator did not enter data. The calculator does not enter in the numbers. The calculator does not make connections between what you are putting in and what you are getting out of it. But I can see where a student would think that. You know, its doing the paper and pencil work for you. But what you have to remember is that the connection is being made in the student's head. And so I disagree with that [statement] – but I can see where they would say that.

These responses indicate that, by the conclusion of the MLS process, these four preservice teachers believed learning with technology encompassed much more than just the computational, arithmetic aspects of mathematics. They included the organizational features of technology, the potential to investigate extensions of a lesson, and the connections made between the content and the technology. As Margie indicated in talking about the individual cells in their Excel spreadsheet, the focus should not be on the cell itself, but on what the cells mean. By demonstrating a more broad definition of mathematics, the preservice teachers recognized that the technology assisted not only with doing the computations faster, but also with providing opportunities for the development of conceptual knowledge in the teachees.

While similarities existed between the four preservice teachers mentioned above, Todd's responses on the final feedback survey were somewhat unique. When asked, "So do you think your students did any math or did the technology do the math?" he replied, "They did math at the end but it was very basic. At the end when they found out it was zero percent chance. The technology was used to do the experiment. In our lesson the math itself could have been done by hand."

Referring to the mathematics as the arithmetic calculation of dividing the number of passing scores (zero) by the number of attempts, he saw no connections between the simulation and the mathematical concept of probability, indicating he still held a limited definition of what constitutes mathematics. This was somewhat puzzling since Todd indicated a broad definition of mathematics in his task-based interview, appearing to revert to a more confined definition of mathematics in the early discussions of his group's lesson, and holding to that definition throughout the MLS process. In an effort to clarify Todd's responses, I conducted a brief, follow-up interview about three months after the conclusion of the research project. A portion of the transcript follows.

Researcher: Remember when I asked you at the conclusion of your group lesson about your definition of math. Do you recall what you said?

Todd: Yes, it is the ability to use numbers to solve real world problems.

Researcher: And then I asked, did your students do math?

Todd: I remember. At first I responded the calculator did all the math, but looking back, the students figured out what empirical probability was and how to analyze it not using the calculator. The calculator made it easier, but the thought process of math was still there having been done by the students.

Researcher: So the calculator helped them with the thought process?

Todd: No, the students had to come up with their own thought process. The only thing the calculator did was it computed the numbers of theoretical probability (meaning empirical probability).

Researcher: So what did the calculator do for them?

Todd: It computed the random numbers (to simulate test answers).

Researcher: Was that math?

Todd: No, but then they did the auto sum, that was math and then the students had to convert the probability fraction to a percentage.

Researcher: So what thought process are you talking about?

Todd: UM

Researcher: Do you see what my confusion is?

Todd: [After a long pause.] Yes. Um, for the student to know what empirical probability is, they had to visualize that themselves by looking at [the fact that] there was zero percent chance out of 15 tries. They had to see that there was zero percent chance of passing with out studying. That is what our project was about.

Researcher: So, the calculating the zero percent was the math?

Todd: Realizing that zero percent was the empirical probability, that was the math needed for that project. The students needed to see that zero percent was the empirical probability of our project.

This conversation provided evidence that Todd's view of mathematics has expanded to include the importance of relational understanding. His use of the terms "visualize" and "realize" imply that the teachees need to make connections between the data collected via the calculator and the concept of probability. With statements such as, "The students had to come up with their own thought process. The only thing the calculator did was it computed the numbers of theoretical probability," Todd demonstrated an awareness that, for the teachees, the "thought process" was actually mathematics at the conceptual level.

Tied to this realization is Todd’s bias against lower-level mathematics, which is indicated by his repeated requests to “bump up” the lesson content. At group meetings, he often indicated a desire to incorporate standard deviation, charts, graphs, theoretical probability calculations, and applications to the content of the lesson. Based on time constraints and the mathematical level of the teachees (College Algebra), the group decision was to keep the content of the lesson as described in the lesson plan. Todd originally found it difficult to concede that the finalized lesson content was really mathematics. Through working with his group members and repeated reflection on the goals of his group's lesson, Todd began to accept that the content of lesson was conceptual for the teachees. By perturbing his belief that the lesson content was primarily procedural knowledge (as he saw it), the MLS process afforded Todd the opportunity to experience an important shift in his understanding of mathematical knowledge: what is procedural knowledge for some is actually conceptual knowledge for others.

While the distinction between various types of mathematical knowledge is not the focus of this research project, the relationship between the preservice teachers' personal definitions of mathematical knowledge and the development of their TPCK is. Two components of TPCK defined by Niess (2005, p. 511) are "knowledge of students’ understandings, thinking, and learning with technology in a particular subject" and "knowledge of curriculua and curriculum materials that integrate technology with learning in the subject area." For the preservice teachers to develop these components of TPCK they should be given opportunities to explore procedural and conceptual understanding (students' understandings) in relation to technology-enhanced lessons (curriculum materials). The evidence above suggests that, while procedural and conceptual forms of mathematical knowledge were not focused upon during the MLS process, the preservice teachers involved did develop an awareness of such types of knowledge in relation to their MLS group lessons, enhancing their TPCK.

Which comes first? During the task-based interview, conducted prior to beginning the MLS process, preservice teachers were asked questions related to the use of technology to enhance student learning in relation to the assigned tasks. During the interviews, four of the preservice teachers, two per group, reflected a belief that it was important to learn the mathematics first, often indicating a need for paper and pencil, before incorporating technology. An emphasis was placed on the need for students to perform step-by-step mathematics in order to "understand" the concept. The following are a few examples of these comments from the task-based-interview transcripts.

> John: I think that the student needs to know how to do it by hand before they start using technology, but technology does provide a good source for manipulatives and for actually showing "why." Like, you can basically show why this works, why you can use the other two methods.
>
> Researcher: On the system of equations you mean?
>
> John: Yes. But they won't always have technology with them so they need to know how to use their own heads to figure it out what to do.
>
> Margie: I think it depends on how far advanced they are. If they can see it without seeing every step worked out [on paper and pencil], then that's fine, but if they don't understand it without all the steps, then I think you've lost them.
>
> Beth: I think with their writing on paper and pen will allow them to have what exactly is going on and to understand what we are doing instead of – here push these buttons and ok this is what I do – I don't know what I do.
>
> Todd: I think they get a lot more once they write it out – once they actually multiply the equation their self [sic] and know they cancel (referring to the applet solving the system of equations).

When barriers to the use of technology are examined, one barrier associated with limited acceptance of technology is a central, primary belief that success with technology results from first knowing the mathematics involved. This is emphasized when teachers insist on making calculations first by hand and only later incorporate the calculator to speed up the busy work

(Turner& Chauvot, 1995). These four preservice teachers reflected this belief, although some more strongly than others. The following data, collected later in the MLS process, indicated that, for these preservice teachers, this belief began to change.

One indication of this shift can be seen in the words used to identify the goal of their respective MLS group lessons when comparing the early feedback forms to the final surveys and interviews. For example, John originally stated that his group lesson goal was for, “the students . . . to learn how to write formulas and learn the basics of using Excel.” By the final interview he had expressed the goal by saying, “We wanted the students to be able to use a spreadsheet a little bit more efficiently. And we wanted the student to recognize the outcomes of using a credit card.” When asked what he meant by “outcomes” John replied, “As far as how the interest affects what they pay as well as how much you pay off per month affects how much you pay.” The technology had become integrated with the mathematical content of the lesson.

A little more subtle shift can be seen in Margie by examining her first goal statement compared to her second. In her first goal, Margie stated, "This lesson explores the relationship between interest and ending balance. Students must create formulas in Excel to help them see the relationship.” In this statement, she refers to the content first and the technology second. Her second goal, on the other hand, read, “The objective of our lesson was to use the technology to help the students create formulas and see how the monthly payments and interest rates affect the ending balance.” In this statement, the emphasis is on the technology, and the technology is identified as a tool to help the teachees understand the mathematics rather than calculate the numbers.

In the TI group, Todd’s goal as late as the third group meeting, but before the lesson was actually taught the first time was, “that the experimental probability starts to equal the theoretical probability.” By the end of the process, he stated, “Our goal of this lesson was that the student should be able make a meaningful connection between probability and the use of technology. We were going to use the technology to prove that it is very unlikely to pass a multiple choice test by 100 percent guessing.” Once again, Todd’s post research comments reflected the technology embedded in the content rather than solely addressing the content.

Beth perhaps believed most strongly in “doing the math first.” From the beginning, Beth placed an emphasis on doing mathematics step-by-step. In the development of the lesson she asked that every step be written out. She indicated that when she tutors she breaks the content down to a step-by-step process. And, as the group member in charge of the handout for their group lesson, her meticulous work on the handout reflected the step-by-step nature of her approach.

Perhaps because of this detailed, orderly structure, Beth is also the most reliant on the use of “paper and pencil” first and technology second as indicated by her statement in the task-based-interview, “I have always been firm on learning it first by hand before you learn it through technology.” This still surfaced, however, in her final interview. When asked how she would modify their group lesson if she taught it again, she stated, “I’ve always been one to start with the written and then move on. So if I had any length of time I would start with the writing so they would basically learn the principles without throwing the technology in there.” She followed that up later with, “So I think with their writing on paper and pen will allow them to have what exactly is going on and to understand what we are doing instead of – here, push these buttons…”

Changing this type of belief requires exposure to alternatives – instances where the technology is used in conjunction with the mathematics (Ertmer, 2005; Ertmer et al., 2007; Turner & Chavot, 1995). Providing this exposure for Beth was accomplished through the MLS process. After participating in the MLS group project and working with her group to develop a technology enhanced lesson, there was indication in the final interview that a slight shift might have taken place. When asked for her personal definition of TPCK, she stated that it meant “helping teachers integrate technology in with the lesson. That way they get an overall view of not just the pen and paper but also being able to use technology with the assignment, because we are advancing more into technology than paper.” While it may be hard for her to admit, she does see the need for technology and the movement to incorporate technology into the lesson. Even though she still holds to the paper and pencil belief as indicated in the prior paragraph, she has also begun to appreciate the incorporation of technology into the classroom.

Beliefs have been shown to be a factor in the incorporation of technological tools into classroom instruction (Ertmer et al., 2007; Turner & Chavot, 1995). The statements of these four preservice teachers provide evidence that the experiences related to working as part of an MLS group can facilitate shifts in technology-related mathematical beliefs. In closing this section, it should be noted that the other two participants, Chloe and Scott, did not indicate a "paper-and-pencil first" belief during their task-based interview, suggesting that if they held such a belief at all, it was not a central belief and did not serve as a factor in their technology-related decisions during the MLS process.

Preservice Teachers Views on Teaching with Technology

"You never know what button is going to get pushed. You never know where somebody is going to be or how they are going to see it. We spend so much time saying we know where they are going to have problems factoring. But with technology . . . it is so new, and I have never taught with the TI-83 and so – I can tell you where a student is going to have trouble factoring but I can't tell you where they are going to have trouble with technology." This was a quote from Chloe's final interview that summarized the theme presented in this section. The preservice teachers are taught such skills in methods classes as how to word specific content questions to solicit expected responses, how to select examples for discovery lessons, how to estimate the time required and the order of presentation for topics in a lesson, and how to perform assessment of student outcomes. In a technology-enhanced lesson, these skills are still necessary, but may take on unique characteristics, and need to be taught (Keating & Evans, 2001). How does a teacher, for example, pace a lesson involving technology when the teachees' level of technology literacy is not known? What vocabulary should be used in asking questions or preparing handouts? And how is technology implemented in a student-centered learning environment? These and other technology-related mathematical pedagogical factors are discussed in the section as they were issues faced by the preservice teachers as they participated in the MLS process.

Pacing and sequencing. One of the first issues considered by the preservice teachers in preparing their lessons was just how much they could cover and in what order. Both groups began with more material than they could cover in a 50 minute class period. The TI group's lesson content was more suited to the 50 minute period than the XL group's content. Yet, even the TI group did not have time at the end of the lesson to discuss, summarize, and review. While the majority of the teachees agreed via their feedback forms that it was not a good idea to use the calculator to select answers to the test, they did not have the opportunity to discuss the theoretical probability and how it related to the experimental probability they had determined through their simulation. The heart of the lesson was short-changed.

The XL group had plans to incorporate graphs of the unpaid balance along with a regression line and discuss the nature of the data as linear or non-linear, investigating what would happen if, for example, the monthly payment doubled, the interest rate changed, or any combination of the two happened. This type of exploration was not uncommon in our College Algebra curriculum. It was, however, never done during the XL lesson, as time ran out. In fact, the pacing was such that in the first lesson the "what if" questions were not even addressed. The second and third lessons contained a very brief discussion of the "what-if" questions, but as indicated by the College Algebra teacher, this was the heart of the lesson and was only given brief coverage.

The ability to predict how much material can be shared in a technology-enhanced lesson takes practice. The MLS process provided some of this practice. In both groups, the third lesson was paced much more in line with the 50-minute class period than the original. By analyzing the lesson video and making changes as needed, each group began to fine-tune its lesson content to fit the allowable time period. Changes made included deleting some of the material in addition to altering pedagogical strategies.

John, the first to teach in the XL group, described the need for one such change in the feedback following his teaching of the group's lesson. He indicated that the teachees took so much time learning to enter formulas into Excel and grasping the auto-fill function that the lesson was not finished. Therefore, the students did not have a chance to see the effects of interest. When asked how he would do it differently, John indicated that he would use a different teaching strategy, perhaps having students work in pairs or offering some "whole class" discussion. These thoughts were discussed with the members of the XL group, and they decided to incorporate these two strategies into their second lesson by providing some "whole class" instruction prior to beginning small group work. This pedagogical change saved enough time during the second presentation to introduce, but not thoroughly discuss, the "what-if" questions at the end of the lesson. The lesson reflection aspect of the MLS process provided the opportunity for the realizations that the pacing needed to be altered and the group interaction aspect of MLS helped to implement strategies to accommodate these alterations. .

The TI group also made a change, but it was in sequencing rather than the pacing of the lesson. Their primary concern following the first presentation was that the technology and the mathematics were not connected. By changing the sequencing of the lesson to randomly generate simulated test responses first and then enter the correct answers second, using the simulated answers to generate a score, they hoped that the content would "flow" better. Feedback from the teachees indicated that it did. This change in sequencing may have offered a fringe benefit for the members of the TI group. The lesson, when used in its original form, was in a more linear format, using a step-by-step process, making little connection between the steps. After making the change, the steps seemed more interconnected for the teachees. By recognizing the need for the interconnectivity, the TI group demonstrated a shift in their original belief that it was best to do the mathematics first, and then introduce the technology. They were accepting that the mathematics and the technology should be interrelated. Reflecting on the effectiveness of their MLS group lesson afforded the opportunity for the preservice teachers to not only examine their belief but also to reexamine the results of making a change that was not in line with their belief. Looking at the feedback from the second group of teachees provided evidence to the preservice teachers that the change was effective, and that perhaps they should reconsider their initial belief.

It is the repetitive cycles of the MLS process that facilitates changes such as these. By allowing the preservice teachers to examine their group's lesson, discuss it as a group, and make collective changes, they were allowed to practice pedagogical strategies related to technology enhanced lessons, developing TPCK.

Written directions. As part of the curriculum in the education program, the preservice teachers receive training in preparing handouts. They become familiar with the vocabulary, phrases, and emphasis that help the students follow the intent of the handout. When technology is involved, the vocabulary, phrasing, and emphasis may require special attention. This became apparent through teachee reactions to both the TI group's and the XL group's lesson handouts.

The TI group began with an established handout, retrieved online from TI.com, but made changes in their document even before the first presentation. It was agreed by the group that the deletion of the "enter" command in relation to the scroll down or press a number (as described in a prior section) would make the directions less confusing. While that was the only change made prior to the first presentation of the lesson, Chloe indicated during her final interview that "One of the things I would change is I would have sat down before Todd [taught] . . . and [gone] word for word through that [handout] and [done] it as a student . . . . That would have made Todd's lesson so much better." Admittedly, the group was not prepared for the teachees' confusion related to the first handout. The opportunity to reflect on teachees' reactions and make modifications accordingly proved to be a valuable component of the MLS process.

Changes made to the TI group's handout for subsequent teachings of their MLS group lesson included the sequencing change mentioned above, but also included changes to calculator commands. These changes included using the “clear entries” function from memory rather than clearing each list, and deleting the 2nd enter command in favor of repeating a process. The importance of these changes was in how it related to the effectiveness of the lesson for the teachees. When technology is involved, any amount of confusion that can be eliminated enhances the effectiveness of the lesson. The changes made to the worksheet were designed with that goal in mind. They made the lesson "flow" better. The decision made while reflecting on the use of technology in presenting the topic and making modifications as needed (TPC6) provided evidence of the development of TPCK.

The XL group designed their own worksheet to accompany their lesson and field tested it prior to use in the classroom by having Margie’s step-mom work through the document. The importance placed on pre-testing the handout parallels Chloe’s comment about the benefit that might have been gained by testing their worksheet prior to its first use. Even this, however, provided no guarantee of success. As indicated in the prior sections, John and Scott observed that the teachees looked at the handout, but the steps performed by the teachees were not reflective of the handout's intent. In many cases, the teachees just stopped, waiting for John to provide assistance. In reflecting on the teachee reception of the handout at their next group meeting, the XL group made changes to the handout. By condensing the wording and changing to a more bulleted format, rather than using complete sentences and paragraphs, they felt the handout would be easier to follow. Teachee reception during the second teaching of the lesson indicated this to be true.

For both the TI and the XL groups, actually incorporating the written directions into a classroom setting and using them with the teachees provided an opportunity for the development of TPCK. The preservice teachers not only used technologies of the subject field in developing learning activities for students (TPC1), but also evaluated the effectiveness of these activities.

Student-centered learning. The overarching goal I established for the MLS project was as follows: to engage the students in exploring mathematical patterns and/or relationships using technological tools to develop a rich understanding of mathematical topics. The definition of TPCK provided to the preservice teachers included the focus on integrating technology in a student-centered learning environment. These two concepts – engaging the students in learning and establishing a student-centered learning environment – were the focus of the modeled lessons presented during the first part of the EME course and were required components of the MLS group lessons.

To help accomplish this goal, both groups prepared a student handout to allow the teachees a written guide to the lesson so that they could follow the guide and be “engaged in learning.” In using the handout, however, the two groups took somewhat different approaches. The TI group opened its lesson with a brief introduction to the topic, and, via the story of Nathan, set the stage for the teachees. The lesson continued as the teacher worked through one simulation of guessing the test answers with the students, showing the steps on the screen via TI-SmartView then allowing the students to continue working in small groups of two, using the handout as a guide while the teacher circulated as a facilitator. Thus the lesson was student-centered and the teachees were engaged in learning, but the teacher was still an active participant.

The introduction portion of the XL group lesson expanded during revisions from a *very* brief introduction and demonstration of data entry to an introduction that included a forewarning of expected difficulties, and, finally, to a more “podium-centered” (as per Scott) lesson for the third presentation. All three of the XL group members, however, demonstrated only minimal steps for the teachees using the computer projection screen. It appeared as if the XL group believed that, in a student-centered learning environment, the teacher should provide only minimal, if any instruction at all. This is apparent in John’s definition for student-centered learning stated during his final interview in which he stated, “[student-centered] means that the students are the center of everything we do and not us as teachers. That means all of our attention should be on the students and students shouldn't be focused on us.” This approach to a student-centered environment may work in some instances, but not in this case, as evidenced by the teachees’ confusion with the written handout. Perhaps this was due to the teachees' lack of familiarity with the technology, or perhaps the lesson was simply not the norm in their classroom and the students felt displaced. In any case, the teachees were not receptive to a completely student-centered, student-controlled environment.

The groups' decisions, though different in nature, each represented decisions related to TPCK; both groups explored what pedagogical strategy would be most effective in presenting the content of their lesson using a technological tool.

Aspects of MLS Facilitating TPCK Changes

Participants' perceptions of the aspects of the MLS process that facilitated changes in TPCK were based primarily on the MLS feedback forms and final interviews. These data were compared to researcher fieldnotes and observations, along with group discussion during the MLS process, to identify the aspects of MLS that facilitated change in the TPCK of the participants.

Group Dynamics

A major component of the MLS process is the interaction between the members of the MLS group as they develop, teach, evaluate, and modify their group lesson. This requires committing major blocks of time, sharing ideas, arriving at a consensus, and willingness to adapt. It requires cooperative learning among the members of the MLS group. Every member of the EME class at some time during the project indicated that participating in the group was a tremendous asset. The feedback focused on two central themes – learning from each other and learning with each other. While these may seem almost the same, the viewpoint is different. Learning from each other involves the opportunities to draw on the strengths of the other group members whereas learning with each other involves developing the skills necessary to be an active, productive member of a cooperative learning group.

Learning from each other. Every member of the EME class indicated that during the MLS process they had learned something from other members of the group in the areas of technology, pedagogy, and/or content. Several of the comments are provided below as examples of the feedback received.

> John: Well, I liked the fact that we did it in groups and we each got to collaborate with the others. And we could take – I think I put this in one of the feedbacks – Margie had her strengths, Scott had his strengths, and I had my strengths. And when we put that all together we ended up with something very good, and it continued to get good as we continued to go through the process of doing feedback on it and making it better. So that was the strongest aspect of it.

> Margie: You have the advantage of ideas coming from more than one person. It is also beneficial for more than one person to critique the lesson.

> Scott: Others see some things I can't. This is one of the best ways to improve. One example is feedback about the worksheet not working properly.

Todd: Planning the lesson on probability we were able to learn more about our calculators from each other and a little more on the subject matter from each other.

Chloe: I was the second person to teach the lesson. I found that I was better prepared and had a better idea of what to do and not to do when it was my turn to teach [after watching Todd].

Beth: In creating the worksheet and going through it with the team and practicing it, I was able to get more familiar with [TI-SmartView] and use it more competently than I would if you just gave it to me and told me to teach this lesson. I would be a duck out of water. That's what watching them do it and little mistakes that they made that I could fix [is what I learned]. That, OK, I shouldn't do this, but I could try it this way and maybe it would work a little better with the technology. So, that’s what I gained from the overall sheet and watching them.

As these preservice teachers indicated, MLS provided an opportunity for the group members to strengthen in all knowledge areas. By pulling on each individual’s strengths not only did the MLS lessons develop but individual members were also provided an opportunity to develop in content, pedagogy, and technology.

One interesting across-group development associated with the preservice teachers learning from each other is the depth of responses provided on the first and second lesson feedback forms. In the process of developing their lessons, sharing ideas, and watching the presentations, the preservice teachers began to focus less on student behavior and more on student thinking. Found in only limited use in the first feedback forms but repeatedly in the second were such phrases as, “focusing more on the math,” “understanding the mathematical patterns,” “students discovered,” and “students understood and demonstrated.” This development in depth of observations is reflective of findings in both lesson study (Lewis, Perry, Hurd et al., 2006) and MLS research (M. Fernández, 2005). At the Highlands School in San Mateo lesson study was introduced into the professional development procedures and school improvement plans. Teachers initially focused on “such easily observed aspects of student behavior as whether students followed directions and treated their peers with respect." Over time they began focusing more on student thinking and their feedback focused on solution strategies, information organization, and the types of errors the students made (Lewis, Perry, Hurd et al., 2006, p. 274). This is supported in the work of M. Fernández (2005), when

"66.7% agreed, via survey, that they grew in their ability to observe strengths and weaknesses in lessons and broadened their areas for consideration when viewing lessons" (p. 44).

While the preservice teachers in this research are simply novices, their comments demonstrate that they are beginning to develop their own lesson study repertoire. As they sharpen their observational skills, and in the process begin to identify strategies, materials, and technologies that expand students' mathematical thinking abilities (TPC2), they will continue to develop TPCK.

Learning with each other. One focus of this research is the preservice teachers' participation in a "cooperative" MLS group. The term cooperative, however, began to take on multiple meanings as the group dynamics for both the TI and the XL group developed.

The TI group dynamics represented the more traditional concept of a “cooperative learning group.” They met frequently as a group and tended to design and modify their lesson plan while at the group meeting. While some tasks were divided among the members and completed after the group meeting, they were still done based on group input. That was not to say, however, that the group was completely harmonious, as seen in the following example.

In relation to their group lesson, Todd tended to focus on the overall big picture – the concept of probability. On several occasions, he expressed a desire to broaden the lesson to incorporate more probability-related skills so the students could make connections with content-area concepts, including such topics as standard deviation, actually calculating the theoretical probability which involved the use of combinations, and relating the lesson to real-world experiences. The detail of the lesson was not his primary focus. Beth, on the other had, wanted to create a lesson handout and a lesson plan that incorporated a detailed outline of the lesson, step-by-step. She wanted everything spelled out so that the handout was a detailed guide for the teachees to follow and the lesson plan was a detailed guide for the preservice teachers to follow. Chloe fell somewhere in between. In working to reconcile their different approaches, the members of the TI group began to realize they were participating in a “real world” experience of learning to work in a professional environment with a group of their peers to accomplish a common goal. Chloe summed this up in her final survey.

> I often feel scattered and unorganized. I know now that group work is a time to put that aside. In order to make a group project work, one must take into consideration the other people sharing the grade, product, and experience. I am grateful for this

> experience not because of the content or technology or pedagogy (although I do know what that word means now) but for the chance to work in an environment I was not entirely happy with. It has better prepared me for the future, a future that surely holds projects, committees, school dances, and interdisciplinary units. This project taught me more about myself than I ever expected.

The dynamics of the XL group were less traditional, but perhaps more reflective of the technological world in which we live. Their schedules and outside commitments prevented them from meeting as often as the TI group. They compensated with email communications. While changes were made via group consultation, the consultation was often electronic, and one member of the group actually entered the changes to the lesson plan, handout, or spreadsheet. The changes were, however, evaluated by the entire group. One example is the incorporation of the macro in the final spreadsheet document. Scott, the member of the group with programming experience, coded the macro, and then shared the spreadsheet via email with the other members of the group. By fulfilling their group responsibility and evaluating the lesson, albeit done individually, they discovered errors that were identified and corrected, thus avoiding confusion in the final presentation of the lesson. The members of the group realized that, even though they were not working together at the same time and place, they were still part of a group and reacted as such. This provided the XL group an opportunity to investigate different cooperative-learning strategies in today's technological society.

As these preservice teachers continue through their professional career they will surely be required to work as part of cooperative groups. The experiences afforded through the MLS process provided a foundation for their future participation in such groups.

Learning by Design

In their work with professional development for teachers, Mishra and Koehler focused on the concept of learning by design (Koehler et al., 2004; Koehler & Mishra, 2005; Mishra & Koehler, 2006). Survey responses by their participants indicated that when the participants design their own product (web site, lesson, etc.) they "are confronted with building a technological artifact while being sensitive to the particular requirements of the subject matter to be taught, the instructional goals to be achieved, and what is possible with the technology" (Koehler & Mishra, 2005, p. 148). The sensitivity to the three areas, technological artifacts, subject matter, and instructional goals, represents an awareness of TPCK.

The preservice teachers involved in my research project were also learning by design. While they did begin with a lesson concept retrieved from the Internet, each group made significant changes to the design of the lesson to accommodate their own lesson objectives, the teachee characteristics, the teachee classroom settings, and the overarching goal set for the MLS lessons. As design changes were made, the preservice teachers were sensitive to the particular technological tool used in the lesson, the subject matter objectives, and the pedagogical style that best fit the presentation of the subject matter with that technological tool. The experience of learning by design as the preservice teachers developed their MLS group lesson provided an opportunity for the development of TPCK.

Situated Learning

It has often been said that we teach as we are taught. If this is true in the area of technology as well, then future teachers will teach technology as they are taught, and that often includes only minimal exposure. If this chain is to be broken, it may require active intervention. Microteaching lesson study has been proposed as one form of intervention (M. Fernández, 2005; M. Fernández & Robinson, 2007; Cavin & Fernández, 2007). It affords preservice teachers the opportunity to experience teaching with technology situated in a classroom environment and to participate in TPCK discourse within a community of practice, both of which have been shown to be important in teacher education programs (Putnam & Borko, 2000). By using students currently enrolled in mathematics classes, preservice teachers received feedback from the students' points of view in addition to the typical mathematics instructor's and teacher educator's points of view. As the MLS groups discussed all the feedback and added their own evaluations of the lesson, they were able to consider what worked and what did not from multiple perspectives as described in the following sections.

TI Group: Teaching the lesson. Part of the MLS process is the actual microteaching done by each individual member of the group. In maintaining a focus on the lesson and the MLS process, I have not emphasized the teaching aspect of the project in the analysis to this point. Its importance, however, should not be minimized (Metcalf et al., 1996). The lesson evaluations and modifications that were an important part of the MLS process were facilitated by observing the microteaching videotapes. In addition, part of the individual progress made by each member of the group was strengthened via the microteaching. This is evidenced at the conclusion of the MLS project in the final surveys and interviews. On the item stating, "The actual teaching of the lesson helped me understand ways of using technology in teaching," the unanimous response was "agree" with the following explanations.

> Todd: Teaching the lesson gave me insight on how helpful the TI-SmartView can be. The students who were lost or unfamiliar on [the] calculator were able to follow the teacher verbatim as the teacher completed the steps on the calculator. The students were able to see the calculator, screen, key history, and the top of my list all at the same time.
>
> Chloe: I learned so much from using the technology. For instance, that time management is crucial when teaching with technology. I had to do several things at one time because different students with different levels of understanding worked at different paces. In terms of the actual technology, I learned more about the calculator and had a nice review of functions that I already knew.
>
> Beth: The best way to learn anything is generally through doing the task yourself. By teaching the lesson and watching my team members teach the lesson, I was able to better use the technology.

On the item stating, "The actual teaching of the lesson helped me broaden my understanding of the topic we taught," all responses were "strongly agree" or "agree," and the explanations were as follows.

> Todd: Of course teaching something is the best way for one to learn the most on a particular subject.
>
> Chloe: Teaching the lesson certainly helped me to broaden my understanding in terms of how students respond and how students understand. I learned that although I understand it, explaining it was a whole different ballgame and created a need to find other ways to verbalize the topic.
>
> Beth: I believe that as we teach, we learn. You learn new things with the things that you teach from other teachers and your students. As with this lesson I learned some different things about teaching styles.

As evidenced in these statements, the group "agreed" that the microteaching portion of the MLS process was important and afforded a valuable learning experience. Both Todd and Beth made note that the best way to learn something is to teach it, and Chloe realized that understanding the material is one thing, but teaching the material is a "whole different ballgame."

Evidence of additional benefits of the microteaching aspect of the MLS process is provided by each member of the TI group. Beth, in her final interview, emphasized the importance she placed on the teachings of the lesson. When asked about the one thing she would NOT take out of the MLS process, she replied, “Watching the videos of each person teaching the lesson, because that’s important or else you don’t know what not to do with yours.”

Chloe's statements that “time management is crucial” and “students with different levels of understanding worked at different paces” indicate pedagogical observations facilitated by the microteaching process. While both of Chloe’s observations apply to lessons that may or may not incorporate technology (thus representing pedagogical content knowledge), when technology is involved, these statements require additional interpretation. Time management, when using a technological tool, is unpredictable. It is difficult to predetermine how long a lesson will take. When unexpected technological errors do occur, such as a student deleting a list, pressing the wrong option, or simply falling behind and announcing they are “lost,” a large portion of the class time may be required for student assistance, causing a loss of momentum in the lesson.

One additional example of the importance of the teaching aspect of MLS in providing opportunities for the development of TPCK is provided by Chloe. When she presented their MLS group lesson, she was not aware that the teachees had not seen their particular technological tool, TI-SmartView, prior to her lesson. The teacher in that class was actually teaching one of her College Algebra classes with the TI-ViewScreen and one with the TI-SmartView with the intention of collecting feedback on the effectiveness of each tool. Chloe's group of teachees had been using the TI-ViewScreen. She realized this only after the conclusion of the lesson, when one teachee feedback form indicated they preferred the TI-ViewScreen to the new technology Chloe had used. In her final interview, Chloe reflected as follows:

> So…maybe if I had known that they had never seen TI-SmartView before I may have used the overhead. Because [the projection method] was not the technology we were using – it was just . . . never something that occurred to me – you just learn things like that. Well, how have they been seeing it? You know. How do you want to do it so that my lesson goes smoother? I’m only going to be there one day. Let’s plan ahead. I probably would have used the overhead had I known about what they were used to seeing, but it was good that they saw the TI-SmartView.

Although Chloe stated, "you just learn things like that," she may not have learned that the method of presentation was an aspect of the technological tool to be considered separate from the graphing calculator itself, without the situated learning aspect of teaching to actual students.

XL Group: Teaching the lesson. In the final MLS feedback survey, the actual teaching of the lesson was seen as important by all three members of the TI group. Feedback from the XL group, however, was quite different. In response to the statements on the final survey that began with “the actual teaching of the lesson helped me understand”, XL group responses were as follows:

> Understand ways of using technology in teaching, 3 “neutral;”
>
> Understand the topic of our lesson, 1 “neutral” (Scott) and 2 “disagree;”
>
> Understand teaching in a student-centered environment, 1 “agree” (Scott) and 2 “neutral.”

In a request to explain their neutrality in many of the responses, the XL group members replied on multiple occasions that they were unclear as to what the question was asking. This was a little puzzling. All three members of the XL group had completed coursework in teaching methods, so the terminology should have been familiar to them. An examination of the preservice teachers' responses to survey questions related to the changes in the lesson plan between consecutive teachings added some insight into the neutrality of the responses stated above.

On the question from the final survey relating to gains in content knowledge, the group members indicated that they “understood it to start with.” Since the content of their lesson was a more common, real-life topic, their self-evaluations reflected that they already knew the material before they began developing or teaching the lesson, thus their gains in content knowledge were seen as neutral. Their self-reported knowledge of Excel and comfort level with the technological tool prior to the MLS process may explain the neutrality of the gains in the area of technology as well.

Responses in the area of pedagogy were different. Margie indicated that from the first to second teaching she realized that the teachees, “need more coaxing to work together” and Scott indicated, “I thought there could be better ways to get the students involved, but [I’m] not sure what they are.” John answered similarly with, "I learned that there are many different ways to teach the same lesson, and some ways are better than others." In the process of personally teaching the lesson and watching the videotapes of the other group members, these preservice teachers were able to recognize weaknesses in their teaching strategies, such as the need for the teachees to work together and the need for the teacher of the lesson to facilitate this cooperativeness. It was the actual teaching of the lesson and watching the teachees' reactions to the pedagogical style in use that allowed for these observations to be made. While their Likert-scale responses reflected minimal gain in understanding a student-centered environment, their open-ended responses to additional questions indicated otherwise.

I observed one additional benefit to the actual teaching of the lesson that was not mentioned by the XL group in any feedback. Each member of the group had the opportunity to deal with technology-related glitches in one form or another while in the process of teaching the lesson. In John's case, he forgot to use the F4 command to lock the cell reference when entering the interest formula, causing errors when he tried to auto-fill the cells. Without getting flustered, he simply entered each interest calculation individually. This may not have been the most efficient technique technologically, and in modeling for the teachees may have led to some confusion. It did, however, allow John to experience the fact that technology glitches can be dealt with, and the lesson can continue.

Margie's technology glitch involved formatting cells in the spreadsheet. When the interest rate was entered, some computers displayed 9.9% while others displayed the decimal equivalent of 0.099. In Scott's group, Chloe's computer developed a visual basic error. In each case, however, the preservice teacher remained composed, handled the glitch, and went on with the lesson. Through the actual teaching of the lesson, the preservice teachers were provided an opportunity to experience an important aspect of TPCK – overcoming technological bugs while maintaining focus on the lesson.

Perhaps the most important aspect of actually teaching the lesson was not related to what the teachers did, but to what the teachees did. As each of the group members indicated, the teachee use of the printed lesson handout did not go as planned. The expectations were that the teachees would follow the handout, and within about 20 minutes have the first year's data entered and the ending balance calculated. This would have allowed the "what if" questions to be discussed more thoroughly. Much to their surprise, the teachees did not respond to the handout as expected. This could only have been observed through the actual microteaching of the lesson. No amount of planning could have predicted this. As John indicated in his formal reflection for the EME class related to this task, “I have discovered that revising taught lessons helps work out the kinks.” Without the “taught” aspect, the kinks would be difficult to determine, much less “work out.” The situated experience with actual classroom students working through the handout afforded the XL group members the opportunity to work through difficulties experienced with their technologically enhanced lesson, developing TPCK.

Reflection and Modification

In an effort to establish credibility for the coding of my data, I sent an interview to a colleague who is also researching TPCK and requested that she code the interview using my coding structure. She did. When she returned the document, one of her general comments was that TPC6 was coded extensively. TPC6 states that the preservice teachers "reflect on the use of technology in presenting the topic and make modifications as needed." Critical reflection has been shown to be an important aspect of teacher training (Collier, 1999; Yost, Sentner, & Forlenza-Bailey, 2000). Incorporating technology into the picture does not change that level of importance.

In typical methods classes, future teachers are often provided opportunities to teach an individual lesson or an individual unit. Feedback is provided by the instructor and perhaps by the classroom teacher, but then the lesson is filed for future reference. It is often a year or more before the lesson is re-taught, if ever. While reflection on the lesson does occur, there is no opportunity provided for determining if suggested improvements to the lesson will prove effective.

Similar to the finding of M. Fernández and Robinson (2007), microteaching lesson study in this research project provided an opportunity for the preservice teacher participants to not only teach a lesson but also to reflect with their peers and their coach on its effectiveness and immediately make modifications so the lesson could be re-taught. After reflecting on students' reactions to the presentations of their lesson, the members of the TI group modified the sequencing of their lesson, and made significant changes to the calculator commands in the handout. After reflecting on students' reactions to the presentations of their lesson, the members of the XL group modified the motivational aspects of the green cells in their lesson and made significant changes to the pedagogical style used during the introduction of their lesson. In both cases, the MLS process provided opportunities for the modifications to be incorporated into a re-teaching of the lesson with a very short delay time, allowing for additional reflection and modification as needed. The preservice teachers could immediately evaluate the effectiveness of their changes, identifying the interrelationship between the content of the lesson, the pedagogical aspects of the presentation, and the technology used via feedback forms and group discussions. The opportunities to reflect and modify allowed the preservice teachers to begin developing a repertoire of knowledge A retired teacher enrolled in the technology class for purposes of professional development once made an unsolicited announcement to the other members of the class, "I want these students (preservice teachers) to realize that they have just accomplished three years of work in three weeks time." That statement summarized the reflection and modification strengths of the MLS process that provided opportunities for the preservice teachers to develop TPCK.

Developing Ownership

Clark and Peterson (1986) discuss teachers' thought processes related to planning, interactive thoughts and decisions (in the classroom), and teachers' theories and beliefs. It is the teacher planning portion that is important here. One study contained in their analysis was focused on a classroom teacher who spent her summer months reexamining the curriculum materials provided by her district in preparation for the following year. As she reflected on the curriculum, she rearranged the sequence of topics, added and deleted content, and created an outline of the material to be taught, how it would be taught, and the pace at which it would be taught. Through her reflection of the prior year, she began to integrate her own experiences with the published curriculum materials, "establishing a sense of ownership and control of content to be taught" (Clark & Peterson, 1986, p. 262). A similar event took place with the MLS groups.

Participation in the MLS process required that the preservice teachers work closely with two of their classmates on a joint project over a four week period. During this time they researched, developed, taught, observed, evaluated, modified, discussed, re-modified, summarized, and submitted a technology-enhanced lesson. As with the teacher described above, they began to integrate their own experiences with the original lesson plan and developed ownership of their respective lessons.

Evidence of ownership in the TI group can be seen in transcripts of their group conversations. During early group meetings the discussion centered on my requirements for the lesson using such terms as "she wants" or "she said." As the group modified the lesson to meet their objectives using their own pedagogical style, they began to use such terms as "we did" or "we felt" or "we thought." In his final interview, Todd sums it up with his statement, "We identified a lesson from TI.com and then manipulated it so that it would match our style.” In shifting the focus from what I required to what they believed, and in developing their style, they demonstrated group ownership of their lesson.

Ownership for the XL group was exhibited in a more non-traditional manner. Due to outside obligations and conflicting schedules, the XL group did not meet face-to-face as often as the TI group. Their persistence in finding ways to work together to complete the task represents a group concept of ownership. Given their situation it would have been understandable that they relinquish the duties of each presentation to the corresponding presenter, but the group found a way to function as a group, jointly preparing their group lesson. A specific example of this united effort is in the review of the final form of the spreadsheet. The XL group was committed to the use of the motivational green cells, but they faced difficulty in making the spreadsheet perform as desired. For the final presentation Scott believed he had solved the problem, and emailed the document to Margie and John. Had they not felt ownership in the lesson, they may have simply allowed Scott to prepare and present. They did not. They reviewed the spreadsheet and discovered an error that Scott had overlooked, allowing a correction to be made before their lesson was presented the final time.

Additional support for the development of ownership can be seen in the parallels drawn between MLS and professional development programs involving lesson study. One factor contributing to successful lesson study in a school-based setting is the fact that lesson study reflects internal ownership and access to external knowledge. While reforms mandated from outside sources often fail for lack of teacher buy-in, teacher-initiated reforms often fail due to minimal access of research-based knowledge (Lewis, Perry, Hurd et al., 2006). The group at the Highlands Elementary school in California, for example, has a six-year history of an effective program, based on a comparison of the school's test scores to the county’s test scores. Their program was established internally by dedicated faculty members and administrators, and yet they frequently solicited outside expertise from resources experienced in the lesson study process. Their success is attributed in part to their combination of both internal ownership and access to external resources (Lewis, Perry, Hurd et al., 2006).

These two components were seen in the development of the MLS groups as well. As each MLS group worked to jointly develop their group lesson, their sense of internal ownership in the lesson appeared to grow. External knowledge was available and often accessed in the form of guidance based on my experiences associated with MLS and teaching technology-enhanced lessons. The combination of these two characteristics contributed to an effective MLS process for the preservice teachers as well, allowing the development of TPCK as they participated in the MLS process.

Summary of Critical Aspects of MLS

In summary, critical aspects of the MLS process that afforded opportunities for TPCK changes to occur included the processes of working as a group to design a technology-enhanced lesson, teaching that lesson in a situated environment, reflecting on and modifying the lesson, and developing a sense of ownership for the final product. The combination of these MLS experiences provided opportunities for, and encouraged development of, technological pedagogical content knowledge in the preservice teachers.

Factors and Barriers

Multiple factors and barriers surfaced that influenced the changes in TPCK that occurred. Maintaining the group case study focus, these factors and barriers will be addressed here as they relate to the decisions made by the preservice teachers on including or not including technological tools into their MLS group lesson.

Modeling

One approach to enriching pedagogical content knowledge in preservice teachers is to have them actively participate as student learners while teacher educators model various teaching strategies. When pre-service teachers participate as students they develop an awareness of the teaching styles modeled by their instructors, and, thus, modeling has a powerful impact on preservice teachers when used by teacher-education faculty (Rahal & Melvin, 1998). This appears to be the case when modeling teaching with technology as well.

When conducting their initial search, the TI group located a lesson using Excel to investigate mean, median, and mode. They made the decision not to select this lesson because, "it took [them] three hours to do [their] first Excel spreadsheet." In their view, the modeled lesson with Excel took too long, thus any lesson with Excel was excluded from their list of options for this particular lesson, constrained to 50-minutes, start to finish.

In the early stages of selecting a lesson and deciding on a technological tool to use with that lesson, the XL group also appeared to be influenced by the lessons modeled during the first part of the EME course. During the planning stages, the XL group referred multiple times to a lesson called "Twins," a lesson they had worked through in the student role where I modeled the instructor role. In this lesson, two twins invested money at the same interest rate, but under different conditions. Twin 1 deposited \$2000 per year from age 25 through 34 while Twin 2 deposited \$2000 per year beginning at age 35, continuing until she retired at age 65. The preservice teachers used an Excel spreadsheet to determine which twin had more money on her 65th birthday by entering initial values for principal and interest rate, and then using the auto fill functions of Excel to calculate ending balance. Both the lesson content and the problem-solving approach in the Twins lesson are similar to those of the XL group's credit card lesson.

The initial software selected by the XL group was TI-Interactive; the software used most extensively in modeled lessons. That choice was changed, however, based somewhat on the influence of a second modeled lesson related to graphing patterns. In that lesson the students entered an expression for an observed pattern for a group of numbers into an Excel spreadsheet. If the entry was correct, the cell would turn colors (red, yellow, or blue). The desire to replicate this motivational technique had an influence on the choice of technological tool for the XL group. They could not make the cells turn green in TI-Interactive, but they could in Excel. The combination of the familiarity with entering data using auto fill functions and the opportunities to provide color-coded motivation for the teachees influenced the selection of the technological tool for the XL group.

Comfort Level

Two factors related to comfort level surfaced during the research in relation to changes in TPCK: the comfort level of the preservice teacher with the tool, and the perceived comfort level of the teachees with the tool. Both factors were evident across MLS groups.

Kersaint et al. (2003) found that while middle and high school mathematics teachers view such technologies as graphing calculators, dynamic geometry software, computer algebraic systems, and data collectors to be of high importance, their comfort level with these technologies is reported to be low. The researchers found the relationship between comfort level and actual integration of specific types of technology in the classroom, however, to be high, indicating that when teachers are comfortable with technology, they are more likely to integrate that technology into their classrooms. Applying this to preservice teachers would suggest that, when preservice teachers are comfortable with a technological tool, they are more likely to integrate that technology into their lessons. Evidence seen in the MLS process supports this idea.

During the initial decision-making process for their lesson selection, the TI group discussed the use of the graphing calculator to run the simulation for randomly guessing answers to a multiple choice test. Before making the final decision, Beth stated, "Let's see if we can master it, then it would be a good thing to do." Chloe added, "We are gonna have to make sure we can do it. Not that we can't do it, but that we can do it in a way that is conducive to a lesson. Because anybody can stand up and read something, you know what I mean?" Beth and Chloe agreed that they must be comfortable in presenting the material in a classroom setting before they made the final selection for the MLS group lesson.

The XL group had a similar concern with the selection of their technological tool. They spent the entire class period designing a lesson using TI-Interactive. As they went home and began to look over the lesson, the group felt that they were not comfortable enough with the software to teach it to a class. They conversed via email and agreed to change their technological tool to Excel. In both cases, the preservice teachers' comfort level with the technology was a factor in the inclusion (or exclusion for the XL group) of the specific technological tool.

Data collected from the preservice teachers both pre and post MLS process add insight into the comfort level factor and its relationship to changes in TPCK. In survey feedback, the preservice teachers indicated their comfort level with a variety of technological tools using a 4-point Likert scale. The shift in comfort level indicated from pre- to post-course feedback is worth addressing. Except for cases where the pre-course comfort level was already at the maximum, it would seem likely that the experience of teaching with a specific technological tool during their MLS group lesson would generate a higher comfort level for both personal and classroom use.

Table 3 shows the results for five of the six preservice teachers associated with the tool used in their respective MLS groups' lesson. Due to personal circumstances, Beth did not complete the final portion of the course which included this post-course survey.

Table 3

Comfort Level with Technology Pre and Post MLS Process

	Pre MLS			Post MLS		
TI Group - Graphing Calculators	Beth	Chloe	Todd	Beth	Chloe	Todd
It is important to incorporate this technology in the classroom.	4	4	4	*	4	4
I am comfortable using this type of technology for personal use.	4	4	4	*	4	4
I am/would be comfortable using this type of technology in the classroom.	4	3	4	*	4	4

	Pre MLS			Post MLS		
XL Group - Spreadsheets	John	Margie	Scott	John	Margie	Scott
It is important to incorporate this technology in the classroom.	3	3	3	3	3	3
I am comfortable using this type of technology for personal use.	3	4	4	3	4	3
I am/would be comfortable using this type of technology in the classroom.	3	3	3	3	4	3

**Due to personal conflicts, Beth did not complete her post-MLS technology survey.*

The data present for the TI group indicates that Todd's comfort level was already at the maximum and remained there, and Chloe's comfort level using the calculator in the classroom, did, as anticipated, reflect an increase. Data for the XL group, however, reflect that only Margie showed an increase in classroom comfort level, while Scott's comfort level actually decreased, and John's remained unchanged. John's lack of increase in comfort level for personal use may be associated with the fact that he, personally, did very little work on actually coding the spreadsheet. Margie prepared the original draft, the group did a few modifications together, and Scott prepared the final version on his own. Since John did not have the opportunity to work with the software on a personal basis, his comfort level did not change. His lack of increase in comfort level using the software in the classroom may be related to the outcome of his teaching of their group lesson. He was the guinea pig, and the feedback from his group indicated that the lesson needed improvement. While every effort was made to emphasize that he was just teaching the group's lesson, there is the possibility that he felt "his lesson" was ineffective, and thus he did not feel any more comfortable teaching with Excel after he taught the MLS group lesson than he did before.

Similar factors may be related to Scott's lack of increase in comfort level, but on an even more personal basis. Scott had spent personal time modifying the Excel spreadsheet to ensure that the cells turned green, a motivational factor that the group felt was important in its lesson. While his modifications did, for the most part, work fine, a few technology-related glitches occurred during the lesson. His personal efforts in preparing the spreadsheet for classroom use were not as effective as he anticipated. While he may have felt very comfortable with Excel after he prepared the spreadsheet, he was not as comfortable after he taught using the spreadsheet.

One factor not seen in the literature but seen repeatedly in the discussion of both MLS groups is the perceived comfort level of the teachees with the technological tool. Group discussions indicate that perceived teachee comfort level influenced both the decision of the TI group to use the graphing calculator rather than Excel, and the XL group to use Excel rather than TI-Interactive. This may be an area for future investigation, since perceived comfort level and actual comfort level may not be the same.

Attitudes Toward Student-centered Learning

Preliminary course data indicated that, of the six preservice teachers, Beth, John and Todd held learner-centered beliefs about learners, learning, and teaching. Chloe held non-learner-centered beliefs about learning and teaching. Data collected on Margie and Scott did not indicate any strong beliefs in either direction. Chloe, Scott, and John had also taken secondary methods classes while Margie had taken both secondary and middle school methods classes; in these classes these students would have been exposed to the concept of a student-centered learning environment. Each group contained a variety of backgrounds among its members in both learner/non-learner-centered beliefs and methods classes. Yet the two groups took substantially different approaches in relation to student-centered instruction.

This variation may actually be related to the comfort level of the preservice teachers with their respective technological tools as described in the preceding paragraph. Teacher comfort level has been shown to be a factor in technology integration into content lessons (Harnish, Connell, & Shope, 2002; Kersaint et al., 2003). The TI group members, who were extremely comfortable with using the calculator, were perhaps also comfortable demonstrating that use for their teachees, leading to a more teacher-centered instructional style. For the XL group, the fact that they were not at maximum comfort level meant that they were comfortable using the technology in the lesson but not comfortable demonstrating that use for the teachees. In a one-on-one situation, answering questions as they circulated, the XL group members were comfortable, but, when they were in front of the class and "all eyes were on the teacher," they were not comfortable, resulting in a less teacher-centered instructional style, indicating, for John at least, that comfort level is a more powerful influence that attitudes toward student-centered learning.

Beliefs About Learning Mathematics

Mathematical knowledge has been categorized by Hiebert & Lefevre (1986) as procedural or conceptual while a similar distinction is made by Skemp (1978, 1987) between instrumental and relational understanding of mathematical concepts. Generalizing these distinctions, procedural knowledge and instrumental understanding are related primarily to computation, syntax, conventions, and algorithms while conceptual knowledge and relational understanding are associated with rich connections between these topics and awareness of when and where they should be applied. "What" is done is compared to "why" it is done. It is important to point out that the authors have indicated advantages to and importance of both categories of knowledge. Such beliefs have been shown to be a factor in the inclusion, or exclusion, of technology in a lesson (Turner & Chauvot, 1995).

As the preservice teachers participated in the MLS process, their views of mathematical knowledge appeared to shift from an emphasis on procedural toward an emphasis on conceptual mathematical knowledge as described in the prior chapter. During their task-based interviews, all the preservice teachers referred to doing mathematics primarily as performing calculations. In discussions related to the use of technology, they simply identified the computational benefit of a technological tool. For example, when considering the applet used to solve a system of equations, the preservice teachers comments were related to the need to see the steps worked out

(Margie), and the use of the applet used in the task-based interview for drill and practice (Chloe and John).

Later in the MLS process a focus on conceptual knowledge began to appear. As it did, the TI group lesson became focused on the connections between the steps completed on the calculator and the probability calculations, and the XL group lesson began to include more of the "what-if" explorations. While these were minor shifts, they suggest that the preservice teachers had begun to recognize the potential of their respective technological tools in helping their teachees develop conceptual knowledge. By shifting their focus from procedural to conceptual knowledge, the associated barrier to the inclusion of technology was reduced.

Beliefs About Teaching Mathematics with Technology

In prior MLS research (M. Fernández, 2005, M. Fernández & Robinson, 2007), preservice teachers were assigned a specific, unfamiliar, mathematical topic for their MLS group lesson. This decision was based on the fact that the teachees were the other members of the class and presenting a lesson on new material provided a mathematical learning opportunity for the teachees as well as the teachers (M. Fernández, 2005; M. Fernández & Robinson, 2007). In my research the focus was on the use of a technological tool, so the topic selection along with the choice of technological tool was left to the members of each MLS group. As described above, several factors influenced these decisions: the comfort level of the teacher and the teachee, the lessons modeled for the preservice teachers, and the preservice teachers' views of mathematics as procedural or conceptual. An additional factor influencing their decisions may have been their belief that mathematics should be done first by hand, with the technology introduced once the concept is mastered, as seen in the research of Turner and Chauvot (1995).

A review of the comments related to the two MLS group lessons shows that, in both cases, the preservice teachers felt the entire lesson could have been "done by hand." It was suggested once by Todd that the teachees simulate randomly guessing answers on a test by bubbling a scantron in a Christmas tree manner. This could have been followed by grading the scantron and calculating the empirical probability of passing the exam. While the calculations for the XL group would have been much more complicated in computing interest and carrying forward the unpaid balance, that group also discussed at one time calculating a month or two by hand prior to filling in the spreadsheet cells so that the teachees could grasp the concept.

By the end of the process, however, the preservice teachers' comments indicated a greater emphasis on the benefit of the technology in accomplishing the goal of their lessons without the “paper and pencil first” requirement. The following statements are taken from the final feedback surveys.

> Margie: For some of the students, they got caught up in trying to figure out how to use the technology that they kind of missed the part of the lesson objectives. For some of the other students, the technology did help them to see the mathematical changes taking place.
>
> Scott: The technology made the lesson move along at a quick pace so we could finish the lesson within fifty minutes [allowing time for the what-if questions].
>
> John: The technology very much helped our lesson. The lesson could have been done without the technology, but the lesson would have become boring and slow.
>
> Todd: By using the calculators to simulate empirical probability the students were able to visualize [a] multiple [choice] test and collectively figure that there is almost a zero percent chance to pass a 20 question, 4 choices per question test. Therefore the students were able to derive probability empirically, but it could have been done by hand. It just would have taken a very long time [and the] students may not have fully understood the lesson. I think the technology did help the student achieve in this lesson.

While Todd still referred to the use of paper and pencil first, he conceded that, if paper and pencil had been used, the lesson would have taken so long that the students "may not have fully understood the lesson." The only way to collect enough data to accomplish the lesson objective was through the use of the calculator. The objective could be accomplished without the use of paper and pencil first. While this belief originally served as a barrier to the incorporation of technology in the lesson, as the preservice teachers reflected on the use of technology in their lessons, and the effectiveness of their lessons throughout the MLS process, their beliefs in “paper and pencil first” were challenged. It has been suggested that "more attention needs to be given to intrinsic factors (beliefs, attitudes, and confidence) during preservice education, as these are perceived as being critical to later success" (Ertmer et al., 2007, p. 58). One strategy for providing this attention to intrinsic factors is participation in the MLS process.

Summary of Factors and Barriers

Factors seen to have an influence on the preservice teachers' decisions related to the use of a technological tool (aside from meeting the requirements of the course) include participation as students in modeled lessons, comfort level of both the teacher and the teachee, the preservice teachers' attitudes toward student-centered learning, and their views of learning and teaching with technology. Participation in the MLS process provided opportunities for preservice teachers to explore their beliefs in each of these areas as they worked through the decision-making process, developing TPCK.

CHAPTER 5

DISCUSSION AND CONCLUSION

In the prior chapter, the focus was placed on the findings from the data analysis as related to the research questions: what changes in TPCK occurred, what aspects of the MLS process afforded opportunities for these changes to occur, and what were possible factors and barriers influencing changes in TPCK? In this chapter, the focus is placed on personal interpretation examining "why" some of the changes may have occurred. Also included are limitations of the research along with implications for future studies.

Discussion

One area of focus in the across-groups data analysis was the development of the written handouts to be used in the group lessons. In particular, the first use of what was perceived by the XL group to be a perfect set of written directions was less than successful. While the teachees were seen to look from the directions, back to the screen, and back to the directions, they did not seem to be following the directions. The XL group, as described in the prior chapter, did make modifications to the handout that helped, but the reasons for the original difficulties with the handout bear further examination. Beyond the standard issues with reading level, I would propose the following possibilities. The teachees, while agreeing to participate in the project, were aware that they would not be held responsible for the material covered in the lesson. While some may have genuinely tried to follow the written directions, based on the lack of graded assessment others may not have put forth the effort. A second, more critical issue may be that the students are not typically given a worksheet and “turned loose.” Worksheets are used nearly every day in College Algebra, but the instructor works through them and the students work along. The emphasis the XL group placed on making the lesson student-centered may have actually proven to be a barrier to the teachees’ acceptance of the lesson. It was simply not what they were used to. They were placed in unfamiliar territory with technology, pedagogy and content, and may not have been prepared to perform in that environment.

What was interesting about the dilemma of the well-prepared handout was the reaction of the members of the XL group. Their primary analysis was similar to the first scenario offered above – the students were not interested or could not read. This may be related to what Clark and Peterson (1986) refer to in addressing attribute theory as the "counter-defensive" attribution (p. 282). They identify two types of attribution theory related to a student’s success and failure.

The first is the "ego-enhancing" (p. 282) which involves the teacher attributing the student's success to him or herself (the teacher) and the student's failures to the student. The second is the counter-defensive in which the attribution is reversed; successes are credited to the student and the teacher takes the responsibility for the failures. The research findings indicate that while teachers in actual classrooms more often exhibited the counter-defensive attributions, teachers in research settings exhibited the ego-enhancing attributions. Since the preservice teachers involved in the MLS process knew they were in a research setting and the students involved were not students in their own classroom, it would seem more likely that they display the ego-enhancing attribution. This appears to have been the case.

Another area of emphasis in the across-group data analysis bearing further investigation is the emphasis placed on doing math using paper and pencil first. While this belief surfaced during the task-based interviews of several participants but seemed less significant during the final interviews, it appeared to be a more lasting belief with Beth. One consideration as to why this may have been a more central belief for Beth, thus making it more difficult to change, may be contributed to her experiences as a tutor in the mathematics lab. When called upon to explain mathematical concepts to students seeking help, Beth turned to paper and pencil, and proceeded to demonstrate the solution to the mathematical problem in a step-by-step manner. With this focus on the rules and procedures leading to the one right answer as part of her daily routine, Beth reinforces her procedural knowledge on a regular basis. Her tutoring responsibilities provide little opportunity to reinforce her conceptual knowledge. Perhaps this is something to be considered in assigning preservice teachers tutoring duties.

One final area of discussion in the findings of the data is related to the group dynamics of the XL group. Although this group was initially established with free time blocks taken into consideration, outside obligations of the group members often prevented face to face meetings of the entire group. The group, however, found a way to adapt. They conducted much of their reflection and modification process electronically. While this was not the traditional approach intended, it did serve as an alternative strategy for the group in meeting the requirements of the project. The question that remains is whether the modifications to the lesson or the TPCK changes that occurred would have been different if the group had conducted more face-to-face meetings, or whether technologically enhanced microteaching lesson study is a viable option?

Limitations

While the two primary components of technological pedagogical content knowledge and microteaching lesson study are fairly broad and are easily transferable to a variety of settings, there are also several limitations on the transferability of this specific research study. As described in the research context, the setting of the study was somewhat unique. The teacher education program in which this study took place is housed at a community college turned college. As such, many of the professors that teach the education courses also teach the content courses. Unlike major universities where the mathematics department and the mathematics education department are two separate entities, at my college they are one and the same. While this could perhaps be considered both a strength and a weakness of the study, it represents a limitation on transferability in two specific areas.

I was the instructor not only for the technology course in which the participants were enrolled, but also for many of the math classes these participants completed prior to participating in the study. This provided, perhaps, a more in-depth personal knowledge of the participants than might occur in a larger university where preliminary course work is completed in a separate content area. While every effort was made to maintain objectivity, there was a personal relationship with the participants that may not exist at a larger institution. Due to the small size of the college, the number of participants in the teacher education program is also small, allowing for a close relationship to exist between the participants. This "family" environment may have influenced such issues as Beth's determination to fulfill her obligations to the course when personal issues surfaced as obstacles, and the XL group's commitment to complete their task when outside obligations interfered. This sense of loyalty may not be transferable to a larger, more impersonal institution.

The context of the research study also afforded opportunities for the mechanics of the MLS process to run smoothly. Since the content-area teachers are in the same department as the teacher education program, they are very cooperative in allowing the preservice teachers access to their students as teachees. As a result of proximity of the content area and education programs, many of these teachees were aware of the teacher education program and were quite willing to share their class time with a prospective teacher. This provided an opportunity to teach in a situated classroom environment that may not be possible in a larger university setting.

One additional limitation on the findings of the study is related to the background data collected. Due to the relatively small number of participants and the exploratory nature of the study, validity data was not established for any of the research-developed data collection instruments. If such issues as comfort level and previous technology experience are considered to be factors in the decisions related to the incorporation of technology into a lesson, the instruments used to collect this data should be validated. This may be a direction taken in future research.

Implications

Implications for Teacher Educators

Several factors related to TPCK development as preservice teachers participate in microteaching lesson study, as well as the factors that enhance or inhibit this development, are of significance to future teacher educators. These are summarized in the following paragraphs.

As we model technology enhanced lessons for our students, it is important that we place an emphasis on using technology for teaching both procedural and conceptual knowledge. Preservice teachers should be made consciously aware of the two types of knowledge through classroom discourse related to whether a specific technology in a specific lesson has been used to enhance procedural knowledge or conceptual knowledge. It is important to include both types of knowledge in classrooms (Hiebert & Lefevre, 1986; Skemp, 1978, 1987), and it is important that preservice teachers are made aware of both so that, as they begin to develop their own technology enhanced lessons, neither will be excluded.

The issue of technological diversity may also become important in future research. As Chloe suggested in referring to her teachees, if in a given group of students, there are x levels of content understanding and y levels of technological understanding, then there may be x times y levels of technological-content understanding, creating an even more diverse group of student understanding. In her final interview, Chloe summarized this thought by referring to the "technological diversity" of the teachees. Chloe and I agreed at the time that technological diversity may be an area for future investigation.

Finally, as we provide opportunities for our preservice teachers to explore the concept of student-centered learning, we need to emphasize the characteristics of a technology enhanced student-centered learning environment. We need to address such issues as forming groups to work with technological tools and the degree of teacher intervention necessary to ensure success with technology-enhanced lessons. As we provide opportunities for our preservice teachers to develop their own teaching skills, we need to address skills related to preparing technology-enhanced lessons. This includes everything from preparing handouts to pacing and sequencing and preparing for the unexpected. These are all teaching skills covered in typical methods classes in relation to traditional lessons that require special attention when the lesson includes working with a technological tool. I would propose that the use of microteaching lesson study is one strategy for teacher education programs that provides opportunities for these issues to be addressed.

Implications for Future Research

Research using this methodology. One question posed to each participant during the final interview was in the form of a request for suggested changes to the methodology used in the MLS process. They had several suggestions. Their primary concern was the use of the lesson feedback forms that I required to be submitted electronically following the viewing of each videotaped lesson. Their opinion was that the amount of time required to complete the form was not worth the benefit received. I realized too late that the required electronic submission was actually the problem. The preservice teachers were watching the video and completing the form by hand, then proceeding to electronically complete and submit the form. Each of the lesson feedback forms was, therefore, filled out twice. While the electronic submission was done in an effort to model effective uses of technology, it actually created a negative attitude toward a much needed form. Next time, written forms will be accepted.

A second recommended change will involve a required group discussion after the third teaching of the lesson. In the current research study, the members of each group were required to combine their lesson documents into one folder for submission, and to individually complete the final survey. They were not, however, required to discuss the third presentation of the lesson since the lesson would not be re-taught a fourth time. This was a missed opportunity. Several unexpected events occurred during the third teaching of both lessons that would have been informative for the participants if discussed during a final evaluative group meeting. These events included the omission of a step in repeating the simulation of Nathan's multiple choice answers, causing one student to get the same number of correct responses every time, along with the coding error in the excel macro related to the cells turning green. A final group meeting would provide an opportunity to discuss such events face-to-face, and would also provide an opportunity for the group to consolidate their documents for submission and complete a joint group evaluation of their lesson and their decision making processes in developing their lesson.

One final change in methodology is related to the modeled lessons. While the lessons served as models for teaching with technology and did include modeling of one feedback session, they did not include modeling of the other aspects of the MLS process. Next time, at least one of the modeled lessons will include a formal written lesson plan (Ertle, Chokshi, & C. Fernandez, 2001), will be videotaped, and will be reflected upon using the lesson feedback forms. This will provide an opportunity for the preservice teachers to experience the mechanics of participating in the MLS process, and questions related to procedures and requirements can be addressed.

Future TPCK related research. Several areas in need of additional research surfaced in relation to the development of TPCK. The relationship between the preservice teachers' view of mathematics (procedural/conceptual) and views of technology integration into a lesson should be explored in more depth. The importance of ownership should be explored. For example, in this methodology, if the topic is assigned rather than selected by the group, will that influence the sense of ownership that develops, and will that have an impact on the development of TPCK? Non-traditional methods of conducting "collaborative group work" should also be explored, such as the email correspondence used by the XL group. In what ways did the non-traditional techniques influence their sense of ownership as well as the development of TPCK in each of the individuals? Recognizing that we are living and teaching in a technology rich environment, is there a way that teacher educators can facilitate this non-traditional technique for conducting the MLS process?

More inquiry into the attitudes and beliefs of the preservice teachers should be conducted prior to beginning the MLS process so that the relationship between this background data to the development of TPCK can be explored. Techniques for establishing a more quantitative measure of TPCK development needs to be designed, tested, and incorporated into future research. Finally, a comparison of the actual implementation of technological tools into classroom lessons by teachers that participated in microteaching lesson study and those that were trained in more traditional teacher education programs should be explored.

Conclusion

The goal of this research was twofold – to add to the literature base for MLS and TPCK, and to explore the changes in TPCK as preservice teachers participate in microteaching lesson study. In addressing the first goal, I believe that by reporting on the activities of both the TI group and the XL group as they worked through the microteaching lesson study process and summarizing the evidence of the development of technological pedagogical content knowledge as they did so, I have made a contribution to the literature related to these two areas.

In addressing the second goal, I offer one final piece of evidence, a statement made by Chloe during our last week of the EME class. The MLS project was complete and I was introducing Geometer's Sketch Pad to the class. Chloe's immediate response to the technology was, “And how would you use this in a class?” She had begun to think beyond the mechanics of the technology and her personal use of the technological tool. She had begun to question the pedagogical strategies to be used along with the technological tool in an effective presentation of content in a classroom setting. With this single statement she provided evidence of an awareness of the decision-making process so intricately involved with the development of technological pedagogical content knowledge.

APPENDIX A

HUMAN SUBJECTS COMMITTEE FORMS

Florida State
UNIVERSITY

Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673 · FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 11/2/2006

To:
Rose Cavin
5098 Old Hickory Circle
Marianna, FL 32446

Dept.: **MIDDLE AND SECONDARY EDUCATION**

From: **Thomas L. Jacobson, Chair**

Re: **Use of Human Subjects in Research**
Developing Technological Pedagogical Content Knowledge in Preservice Teachers Through Microteaching Lesson Study

The forms that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and two members of the Human Subjects Committee. Your project is determined to be Exempt per 45 CFR § 46.(b) and has been approved by an accelerated review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If the project has not been completed by **10/31/2007** you must request renewed approval for continuation of the project.

You are advised that any change in protocol in this project must be approved by resubmission of the project to the Committee for approval. Also, the principal investigator must promptly report, in writing, any unexpected problems causing risks to research subjects or others.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols of such investigations as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Protection from Research Risks. The Assurance Number is IRB00000446.

Cc: Maria Fernandez
HSC# 2006.0881

Informed Consent Form – Primary Participants
Preservice Teacher Enrolled in EME 3410

I freely and voluntarily and without element of force or coercion, consent to be a participant in the research project entitled "Developing Technological Pedagogical Content Knowledge in Preservice Teachers through Microteaching and Lesson Study."

This research is being conducted by Rose Cavin, a graduate student at Florida State University, under the supervision of Maria L. Fernandez, Ph.D. I understand the purpose of the study is to better understand the development of pedagogical skills related to the incorporation of technology in content area lessons, and will involve teaching a lesson developed through participation in a lesson study group. I understand that if I participate in the project I will allow the researchers to analyze and maintain copies of documents and videos created as part of my regular coursework in EME 3410, however all names and other identifying information will be removed.

I understand that my participation in this study is strictly voluntary. If I choose not to participate there will be no penalty. It will not affect my grade for EME 3410, and I can withdraw from the study at any time.

If I choose to participate in the investigation, I will also be asked to participate in approximately two one-hour interviews. During these interviews I will be asked questions related to the experience under investigation and my background in the area of mathematics education and technology. Interviews will be conducted by Ms. Cavin or Dr. Fernandez and will be recorded as referential data. The total time commitment for the interviews will be approximately two hours.

I understand that all documents as well as audio- and video-tapes made during the study will be kept by the researcher in a locked cabinet in her office, room 123D at Chipola College, for the duration of the project. Only the researcher will have access to these documents and tapes, and all tapes will be destroyed by May 31, 2012. I understand my name will not be known or reported in any published research that results from this study, and that information obtained during the course of the study will remain confidential to the extent allowed by law.

I understand there are no foreseeable risks or discomforts beyond those routinely associated with normal day-to-day activities and functions. However, if any discomfort arises as a result of the study, participation can stop immediately and if requested I will be directed to someone to discuss my discomfort. If I have questions about my rights as a participant in this research, or if I feel I have been placed at risk, I can contact the Chair of the Human Subjects Committee, Institutional Review Board, through the FSU Office of the Vice President for Research at 850-644-8633.

I understand I will not be paid, but that there are benefits for participating in this research project. I will be providing teacher educators with valuable insight into the learning of pre-service teachers in preparing lessons that incorporate the use of technology. This knowledge will assist them in developing novice teaching experiences that better fit the needs of pre-service teachers. Additionally, my own awareness about my role as a novice teacher and knowledge about novice teacher development may be increased.

I understand that this consent may be withdrawn at any time without prejudice, penalty or loss of benefits to which I am otherwise entitled. I have been given the right to ask and have answered any inquiry concerning the study. Questions, if any, have been answered to my satisfaction.

I understand that I may contact Rose Cavin, Chipola College, D123E, (850) 718-2382, cavinr@chipola.edu or Dr. Maria L. Fernandez, Florida State University, College of Education, MCH 209, (850) 644-8429, fernande@coe.fsu.edu for answers to questions about this research or my rights. Group results will be sent to me upon my request.

My signature below indicates my decision related to this project.

I am 18 or older, I have read and understand this consent form, and I agree to participate in the project.

______________________________ ____________________

Participant Signature Date

I am 18 or older, I have read and understand this consent form, but I would prefer not to participate in the project.

______________________________ ____________________

Participant Signature Date

I am under 18 and elect not to participate in the project.

______________________________ ____________________

Participant Signature Date

Informed Consent Form – Supplemental Participants
Classroom Students/Audience

I freely and voluntarily and without element of force or coercion, consent to be a participant in the research project entitled "Developing Technological Pedagogical Content Knowledge in Preservice Teachers through Microteaching and Lesson Study."

This research is being conducted by Rose Cavin, a graduate student at Florida State University, under the supervision of Maria L. Fernandez, Ph.D. I understand the purpose of the study is to assist pre-service teachers in the development of well-refined lessons in math and science that incorporate the use of technology by allowing participants to teach the lessons and then reflect on their instruction as part of a lesson study group.

I understand that if I participate in the project I will serve as a student in a classroom setting, and will actively participate in the lesson as presented by the pre-service teacher(s). I also understand that the lesson will be video-taped to allow the pre-service teachers to reflect upon their instructional techniques. These video-tapes will be kept by the researcher in a locked cabinet in her office for the duration of the project. Only the researcher will have access to these tapes and they will be destroyed by May 31, 2012. I understand my name will not be known or reported in any published research that results from this study, and that information obtained during the course of the study will remain confidential to the extent allowed by law.

I understand that my participation in this study is strictly voluntary. If I choose not to participate there will be no penalty. It will not affect my grade in the course for which I am currently enrolled, and I can withdraw from the study at any time.

I understand there are no foreseeable risks or discomforts beyond those routinely associated with normal day-to-day activities and functions. However, if any discomfort arises as a result of the study, participation can stop immediately and if requested I will be directed to someone to discuss my discomfort. If I have questions about my rights as a participant in this research, or if I feel I have been placed at risk, I can contact the Chair of the Human Subjects Committee, Institutional Review Board, through the FSU Office of the Vice President for Research at 850-644-8633.

I understand I will not be paid, but that there are benefits for participating in this research project. I will be providing teacher educators with valuable insight into the learning of pre-service teachers in preparing lessons that incorporate the use of technology. This knowledge will assist them in developing teaching experiences that better fit the needs of pre-service teachers.

I understand that this consent may be withdrawn at any time without prejudice, penalty or loss of benefits to which I am otherwise entitled. I have been given the right to ask and have answered any inquiry concerning the study. Questions, if any, have been answered to my satisfaction.

I understand that I may contact Rose Cavin, Chipola College, D 123E, (850) 718-2382, cavinr@chipola.edu or Dr. Maria L. Fernandez, Florida State University, College of Education, MCH 209, (850) 644-8429, fernande@coe.fsu.edu for answers to questions about this research or my rights. Group results will be sent to me upon my request.

My signature below indicates my decision related to this project.

I am 18 or older, I have read and understand this consent form, and I agree to participate in the project.

______________________________________ ______________________

Participant Signature Date

I am 18 or older, I have read and understand this consent form, but I would prefer not to participate in the project.

______________________________________ ______________________

Participant Signature Date

I am under 18 and elect not to participate in the project.

______________________________________ ______________________

Participant Signature Date

FLORIDA STATE UNIVERSITY
Approved: 11/1/06
HS No. 06-0881
Void After 10/31/07
INSTITUTIONAL REVIEW BOARD

Chipola Permission Form

Consent Form to Conduct
Research - Chipola College

I have read the letter of consent to be signed by the participants in the research of Rose Cavin under the supervision of Dr. Maria Fernandez and give my permission for Rose to conduct this research on the Chipola campus as part of her course, EME 3410, during the Spring semester of 2007. I understand there are no foreseeable risks or discomforts beyond those routinely associated with normal day-to-day activities and functions. However, if any discomfort arises as a result of the study, participation can stop immediately and if requested participants will be directed to someone to discuss their discomfort. If participants have questions about their rights as a participant in this research, or if they feel they have been placed at risk, they can contact the Chair of the Human Subjects Committee, Institutional Review Board, through the FSU Office of the Vice President for Research at 850-644-8633, or Dr. Sarah Clemmons, Academic Dean of Chipola College, at 850-526-2761.

Lou Cleveland — 10/19/06

(Signature) (Date)

Dr. Lou Cleveland,
Division Chair, Math and Natural Sciences
(Immediate Supervisor)

Sarah Clemmons — 10/26/06

(Signature) (Date)

Dr. Sarah Clemmons
Academic Dean, Chipola College

APPENDIX B

(MODELED) LESSON REFLECTION FORM

Name: ________________________

Lesson title: ________________________________

This form should be completed on the computer and linked to your assignment log next to the associated lesson.
As you complete this form keep in mind the overarching goal of our research lessons:

> To engage the students in exploring mathematical patterns and/or relationships using technological tools to develop a rich understanding of mathematical topics.

1. Identify the subject-area content of the lesson and relate this content to the Sunshine State Standards.
2. Describe the technology used and how it was used in the lesson.
3. Identify the teaching strategy used in presenting the lesson. Was it appropriate for this lesson and content?
4. How did the teaching strategy serve to engage the students in learning mathematics with technology?
5. Identify any pros or cons in using the technology to present the content of the lesson. How would this lesson be different (better or worse) if technology was not used?
6. Identify any difficulties that occurred in presenting the content of the lesson.
7. Describe how the lesson accomplished (or did not accomplish) the overarching goal of the lesson study.
8. What changes would you suggest making when the lesson is presented again?

APPENDIX C

TASK BASED INTERVIEW PROTOCOL

1) Please solve the system of equations at the right labeled "Task A" using paper and pencil. Enter your answer here: 2) Briefly describe what procedures you used to solve the system in Task A.	Task A: Solve the system of equations. y = 2x - 9 6x – 6y = 24
3) Please solve the system of equations given as Task B. You may use a technological tool if you prefer. 4) Briefly describe how you used the technological tool to solve the system of equations (if applicable). 5) Explain in your own words "WHY" the technique you used in questions 3 and 4 provide the solution to the system of equations. 6) a)If you were to select a second technological tool to solve Task B, what would you select, and what procedures would you use? b) Perhaps add: Why do you think you chose the first tool first and the second tool as a second choice? c) Perhaps add: If you were doing this with a class of middle school students, would your choice of technological tools remain the same? Why or why not?	Task B: Solve this system of equations. 27.95x + .15y = 4.81 y = 8.23x + 15.95
Consider this problem as the topic of a lesson for your Algebra I class. *Civic organizations sometimes sponsor events to raise money for local charities. Each year, the San Antonio Latino Forum holds a Chili Bash to raise scholarship funds for local students. Forum members have set a goal of raising $15,000 this year. Most of the costs for the event have*	

been underwritten by local businesses. Costs that must be met through ticket sales will be $2400 for advertising and $1280 in miscellaneous costs, plus $2.25 for each meal served at the event. Tickets sell for $8.   *The week before the event, the president of the forum asks the organizing committee to calculate the number of tickets that must be sold in order to meet the organization's fund-raising goal.*   *How might the amount that is raised be affected if the organization raises the price of a ticket? How might the solution be affected if the ticket price is lowered? Explain your answers. (Gerver, R. et al., 1997)*
7) Suppose your college supervisor was coming to observe you teach a lesson using technology - What technological tool would you use with your students in presenting this lesson, and how would you use it?
8) Why did you select this particular type of technology for this problem?
9) What hesitations, if any, would you have about using technology in this problem?
10) Would the use of technology enrich the learning experience for the students? Why or why not?
Press control-click on the link below. If you receive a message that some files contain a virus, asking if you would like to open the file, click on OK. This will open an "applet" for solving systems of equations. Read the directions in the applet and then solve a few of the sample problems. Then respond to questions 11 and 12. Link: applet   This applet can also be accessed from the web at http://www.howe-two.com/free/equations/index.html
11) What were the basic procedures you used to solve the equations with the applet?
12) Would you consider this applet an effective technological tool? Why or why not?

Add any other general comments you would like to share about using technological tools in mathematical lessons.

APPENDIX D
PERSONAL HISTORY
Student Information Sheet

Name as it appears on your permanent record:

____

Name you would like to be called: ____

Social Security Number: ________________________

Address: ____

____

Phone Number(s): ____

Email address: ____

Reason for taking this course:

______ Enrolled in the Mathematics Education program at Chipola
______ Enrolled in the Science Education program at Chipola
______ Teacher recertification
______ Other – please explain

I have taken EME 2040: _____ at Chipola _____ at another institution ______ Not taken.

On a scale of 1 to 10, where 10 is extremely technologically literate, I rate myself at level _____.

Please respond to the following questions below, continuing your responses on the back if necessary.

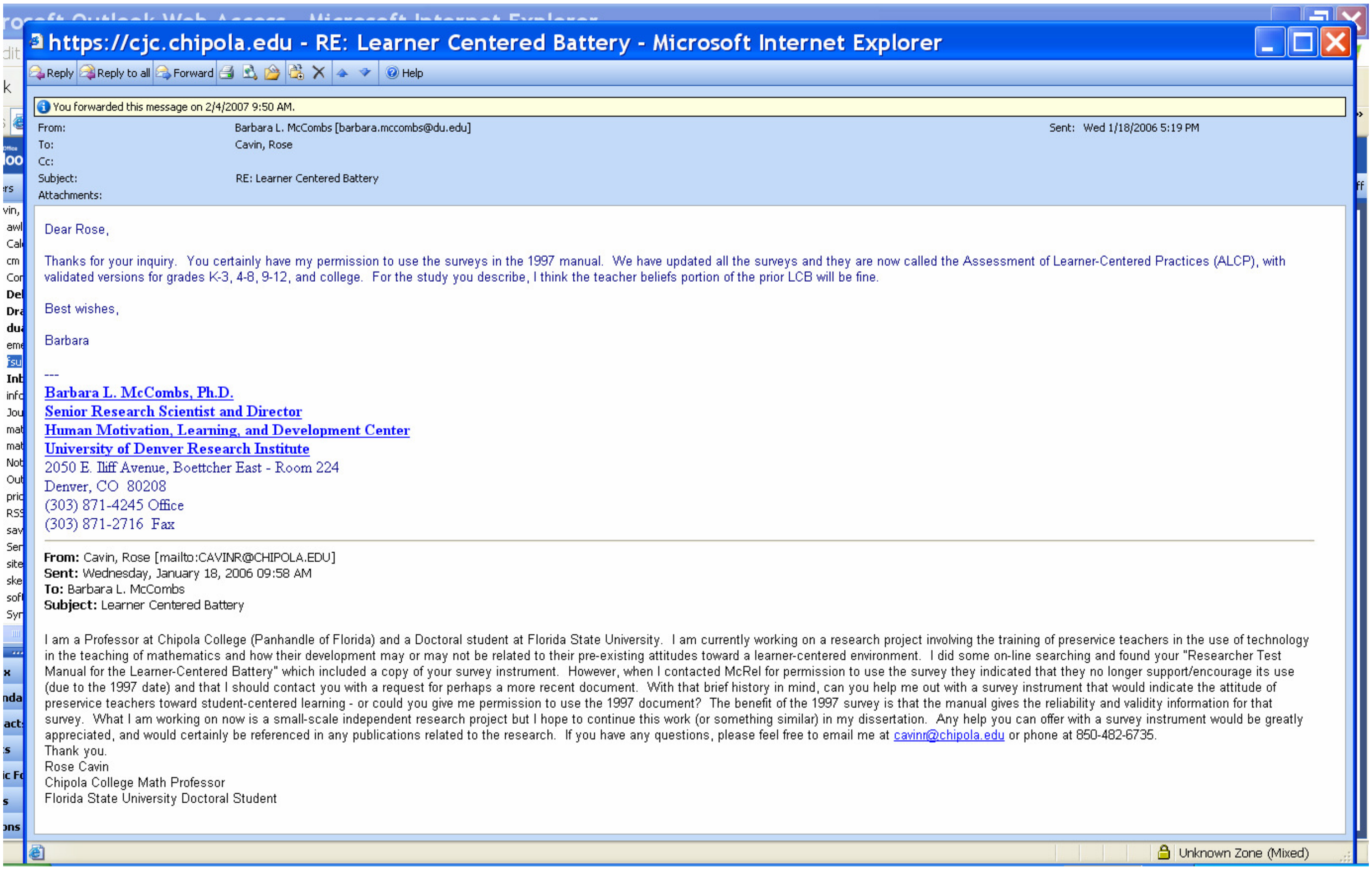
1. Please give me a brief summary of your educational and teaching experiences. Make sure you include the lessons you have taught while taking a practicum or substitute teaching.

2. Please give me a brief summary of your experiences using technology – i.e. in what aspects have you used the computer and/or other technology devises. Be sure to include any technology you used in teaching experiences as well as personal experiences.

3. Please give a brief summary of what you expect to get out of this class.

APPENDIX E

EMAIL PERMISSION TO USE THE LEARNER-CENTERED BATTERY



https://cjc.chipola.edu - RE: Learner Centered Battery - Microsoft Internet Explorer

Reply | Reply to all | Forward | Help

You forwarded this message on 2/4/2007 9:50 AM.

From: Barbara L. McCombs [barbara.mccombs@du.edu]
Sent: Wed 1/18/2006 5:19 PM
To: Cavin, Rose
Cc:
Subject: RE: Learner Centered Battery
Attachments:

Dear Rose,

Thanks for your inquiry. You certainly have my permission to use the surveys in the 1997 manual. We have updated all the surveys and they are now called the Assessment of Learner-Centered Practices (ALCP), with validated versions for grades K-3, 4-8, 9-12, and college. For the study you describe, I think the teacher beliefs portion of the prior LCB will be fine.

Best wishes,

Barbara

Barbara L. McCombs, Ph.D.
Senior Research Scientist and Director
Human Motivation, Learning, and Development Center
University of Denver Research Institute
2050 E. Iliff Avenue, Boettcher East - Room 224
Denver, CO 80208
(303) 871-4245 Office
(303) 871-2716 Fax

From: Cavin, Rose [mailto:CAVINR@CHIPOLA.EDU]
Sent: Wednesday, January 18, 2006 09:58 AM
To: Barbara L. McCombs
Subject: Learner Centered Battery

I am a Professor at Chipola College (Panhandle of Florida) and a Doctoral student at Florida State University. I am currently working on a research project involving the training of preservice teachers in the use of technology in the teaching of mathematics and how their development may or may not be related to their pre-existing attitudes toward a learner-centered environment. I did some on-line searching and found your "Researcher Test Manual for the Learner-Centered Battery" which included a copy of your survey instrument. However, when I contacted McRel for permission to use the survey they indicated that they no longer support/encourage its use (due to the 1997 date) and that I should contact you with a request for perhaps a more recent document. With that brief history in mind, can you help me out with a survey instrument that would indicate the attitude of preservice teachers toward student-centered learning - or could you give me permission to use the 1997 document? The benefit of the 1997 survey is that the manual gives the reliability and validity information for that survey. What I am working on now is a small-scale independent research project but I hope to continue this work (or something similar) in my dissertation. Any help you can offer with a survey instrument would be greatly appreciated, and would certainly be referenced in any publications related to the research. If you have any questions, please feel free to email me at cavinr@chipola.edu or phone at 850-482-6735.
Thank you.
Rose Cavin
Chipola College Math Professor
Florida State University Doctoral Student

Unknown Zone (Mixed)

APPENDIX F

COMFORT-LEVEL SURVEY

For each of the following technology resources indicate your response to the first three statements from a teacher or future teacher perspective using the code: SD = Strongly Disagree, D = Somewhat Disagree, A = Somewhat Agree, SA = Strongly Agree. Then respond to the open ended questions for each technology resource from either a student perspective or a teacher/future teacher perspective, but please indicate the perspective in your response. For example, in responding to the "World Wide Web" you may indicate that, "I have used the web as a student to locate information on……", or "I have used the web as a teacher in preparing/presenting a lesson on……". If you have no experience or opinion for a particular resource it is ok to leave that item blank.

World Wide Web	SD	D	A	SA
It is important to incorporate this technology in the classroom.				
I am comfortable using this type of technology for personal use.				
I am/would be comfortable using this type of technology in the classroom.				
I have used this type of technology in a classroom setting in the following way(s).				
I believe this type of technology should be used in the classroom in the following way(s).				
PowerPoint Presentations	SD	D	A	SA
It is important to incorporate this technology in the classroom.				
I am comfortable using this type of technology for personal use.				
I am/would be comfortable using this type of technology in the classroom.				
I have used this type of technology in a classroom setting in the following way(s).				
I believe this type of technology should be used in the classroom in the following way(s).				
Spreadsheets	SD	D	A	SA
It is important to incorporate this technology in the classroom.				
I am comfortable using this type of technology for personal use.				
I am/would be comfortable using this type of technology in the classroom.				
I have used this type of technology in a classroom setting in the following way(s).				
I believe this type of technology should be used in the classroom in the following way(s).				
Geometers Sketch Pad	SD	D	A	SA
It is important to incorporate this technology in the classroom.				
I am comfortable using this type of technology for personal use.				
I am/would be comfortable using this type of technology in the classroom.				
I have used this type of technology in a classroom setting in the following way(s).				

I believe this type of technology should be used in the classroom in the following way(s).				
TI-Interactive	SD	D	A	SA
It is important to incorporate this technology in the classroom.				
I am comfortable using this type of technology for personal use.				
I am/would be comfortable using this type of technology in the classroom.				
I have used this type of technology in a classroom setting in the following way(s).				
I believe this type of technology should be used in the classroom in the following way(s).				
Graphing Calculators	SD	D	A	SA
It is important to incorporate this technology in the classroom.				
I am comfortable using this type of technology for personal use.				
I am/would be comfortable using this type of technology in the classroom.				
I have used this type of technology in a classroom setting in the following way(s).				
I believe this type of technology should be used in the classroom in the following way(s).				
Probes/Data Collectors (CBRs and CBLs)	SD	D	A	SA
It is important to incorporate this technology in the classroom.				
I am comfortable using this type of technology for personal use.				
I am/would be comfortable using this type of technology in the classroom.				
I have used this type of technology in a classroom setting in the following way(s).				
I believe this type of technology should be used in the classroom in the following way(s).				
OTHER – Please Identify:_______________________________	SD	D	A	SA
It is important to incorporate this technology in the classroom.				
I am comfortable using this type of technology for personal use.				
I am/would be comfortable using this type of technology in the classroom.				
I have used this type of technology in a classroom setting in the following way(s).				
I believe this type of technology should be used in the classroom in the following way(s).				

APPENDIX G

LESSON PLAN FORMAT

(Ertle, Chokshi, & C. Fernandez, 2001)

Group Members:

Date lesson will be taught:

Time lesson will begin:

Classroom Teacher Name:

Brief description of the class:

Hour and Location:

I. Goal of the Micro-Teaching Lesson Study Group: To engage the students in exploring mathematical patterns and/or relationships using technological tools to develop a rich understanding of mathematical topics.

II. Lesson Information

A. Title of the lesson:

Goal(s) of the lesson:

How this lesson is related to the overarching lesson study goal:

How this lesson related to the curriculum:

Process of the study lesson:

Steps of the lesson: learning activities and key questions (and time allocation)	Student activities/ expected student reactions or responses	Teacher's response to student reactions / Things to remember	Goals and Method(s) of evaluation	Notes

III. Evaluation (Assessment)

Notes on completing the lesson plan chart (Step IIE)

This is a chart of the planned lesson sequence. It represents the bulk of the lesson plan, and often spans a number of pages. It describes what you have planned and expect to happen from the beginning of the lesson until the end.

Steps of the lesson: learning activities and key questions (and time allocation)	Student activities/ expected student reactions or responses	Teacher's response to student reactions / Things to remember	Goals and Method(s) of evaluation
This column is usually laid out in order by the parts of the lesson (e.g., launch, investigation, congress. extension applications, etc.), and also includes the allocation of time for each of these parts. *This column should also include a description of key questions or activities that are intended to move the lesson from one point to another.*	*This column describes what students will be doing during the lesson, and their anticipated reactions or responses to questions problems you will present.*	*This column describes things that you want to remember to do not to do within the lesson as well as other reminders to yourself. Also, as you have anticipated student responses and reactions (previous column), this column provides a place where you can think through how you might use those responses and reactions in synthesizing a true learning experience within your classroom.*	*This column describes the goals that are being focused upon during each part of the lesson, and for each activity problem.* *It should also include a concrete description of how you will determine that you have achieved each of these goals.*

APPENDIX H

LESSON FEEDBACK FORM - 1ST PRESENTATION

Name: ________________________

Lesson title: ________________________________

As you complete this form keep in mind the overarching goal of the research lesson:

To engage the students in exploring mathematical patterns and/or relationships using technological tools to develop a rich understanding of mathematical topics.

Feel free to write on the back if more space is required to provide your response.

1. Identify the subject-area content of the lesson and relate this content to the Sunshine State Standards.
2. Describe the technology used and how it was used in presenting the lesson.
3. Identify the teaching strategy used in presenting the lesson. Was it appropriate for this lesson and content?
4. How did the teaching strategy serve to engage the students in learning mathematics with technology?
5. Identify any pros or cons in using the technology to present the content of the lesson. How would this lesson be different (better or worse) if technology was not used?
6. Identify any difficulties that occurred in presenting the content of the lesson.
7. Describe how the lesson accomplished (or did not accomplish) the overarching goal of the lesson study.
8. What changes would you suggest making when the lesson is presented again?

APPENDIX I

LESSON FEEDBACK FORM - 2ND PRESENTATION

Name: ________________________

Lesson title: ________________________________

As you complete this form keep in mind the overarching goal of the research lesson:

To engage the students in exploring mathematical patterns and/or relationships using technological tools to develop a rich understanding of mathematical topics.

Feel free to write on the back if more space is required to provide your response.

1. Describe any changes made in the technology used between the first and second presentations.
2. How did this change (if any) improve the lesson?
3. Identify any changes made in the teaching strategy used between the first and second presentation of the lesson.
4. How did the change (if any) in the teaching strategy help to engage the students in learning mathematics with technology?
5. Identify any difficulties that remain with presenting the content of the lesson.
6. Describe how the lesson accomplished (or did not accomplish) the overarching goal of the lesson study.
7. What changes would you suggest making for the final lesson presentation?

APPENDIX J

GROUP LESSONS

(Ertle, Chokshi, & C. Fernandez, 2001)

TI Group Lesson Plan

Group Members: Todd, Beth, Chloe (using pseudonyms)

Date lesson will be taught:

Time lesson will begin:

Classroom Teacher Name:

Brief description of the class:

Hour and Location:

Material needed: TI-83 calculator, pencil

Goal of the Micro-Teaching Lesson Study Group: To engage the students in exploring mathematical patterns and/or relationships using technological tools to develop a rich understanding of mathematical topics.

Lesson Information

Title of the lesson: You're Probably Right, It's Wrong

Goal(s) of the lesson: The student should be able make a meaningful connection between probability and the use of technology.

How this lesson is related to the overarching lesson study goal: This lesson will enable students to accurately solve probability questions by using the TI-83.

How this lesson relates to the curriculum: M-4 Use appropriate technology to enhance mathematical thinking and understanding and to solve mathematical problems and judge the reasonableness of the results.

Key for Lesson Plan Chart		
Red	Blue	Highlighted
First Change/Added Text	Second Change/Added Text	Removed Text

Process of the study lesson:

Steps of the lesson: learning activities and key	Student activities/	Teacher's response to	Goals and Method(s) of	Notes

questions (and time allocation)	expected student reactions or responses	student reactions / Things to remember	evaluation	
Introduction (5-7 minutes)	Ask the questions "What is probability?" "What is experimental probability?" Allow students to raise hands and speculate on the definitions.Take out Students will be asked a pre-activity question as a class. "*What do you think the chances of passing a test are without studying and merely guessing?*" The students will then be given a handout for their use in the in-class activity. This hand-out will give the steps to find the probability of passing a test by guessing with the use of a TI-83 calculator. It will be important to remember that although these students have heard of probability and have had practice with the TI-83 calculator, they	Give the definition of **probability.** ***The extent to which something is likely to happen***. Take out Probability is used extensively in areas such as statistics, mathematics, science, and philosophy to draw conclusions about the likelihood of potential events and the underlying mechanics of complex systems. In mathematics, probabilities always lie between **zero** and **one**. An impossible event has a probability of 0, and a certain event has a probability of 1. http://en.wikipedia.org/wiki/Probability. Experimental Probability is finding the likelihood that something will happen by performing an experiment	The students should understand that they will be following instructions from a worksheet in order to find the probability of passing a test without studying. In addition they should understand what probability is and where it can be applied in a real-life situation.	The instructor needs to make sure that students are listening to the explanation about probability and experimental probability. take out and its importance in real-life. It is also important to get the students engaged through the introduction to ensure a positive learning experience when performing the activity.

	may have never used the two together.			
Body/Procedure (25-30 minutes)	Ask the question "Have any of you ever strictly guessed on a test?" Give a brief summary of what the lesson will be about (understanding experimental probability through the use of the TI-83) and read the paragraph from the activity (Have someone volunteer to read the paragraph on Nathan) that has the story about the student who has not studied. Ask if there are any questions before the lesson gets started. The instructor will begin the activity by asking everyone to follow along with the worksheet and watch the overhead while the first demonstration is performed. (see changes made to worksheet) The	After performing the indicated operation once for the students, the instructor will need to circulate the room while the students are performing the given operations on their calculators in order to answer questions or give help on the use of the calculator. If there are questions on probability the instructor, based on time, will need to answer as many as he or she can and then move on. He or she may also want to repeat the definition of probability and possibly write it on the board.	The students will be able to find the probability of any scenario given the correct information and a TI-83 calculator. They should be able to Take out explain why they were able to find the probability by use of the calculator and why it works. give the definition for experimental probability and how the calculator facilitated there findings. They should also be able to verbally give the instructor their own findings and be able to explain what their findings mean. This will also serve as an evaluation for the instructor on how well	The instructor will need to pay close attention to the time and allow for as many simulations as possible. There needs to be time for at least 3 times per student but 5 per student will allow for more accuracy.

	students should be made aware that they will be performing the same operation 3-5 times on their own. It will be imperative to the success of the lesson to watch the time closely. The students may have questions concerning the use of the calculator. It is also possible that students could have a number of questions about probability.		they understand the activity and how well they were able to use the technology.	
Review/Closure 10-12 minutes	The instructor will use a tally system by transparency to calculate the findings from the students. (attachment B) The instructor will ask each student how many times they would have passed had they used their calculator to generate answers. Take out The teacher will go student by student asking the question "*What is the probability that you will pass a*	Students will have the opportunity to ask the instructor and their fellow classmates about the findings. They will also be encouraged to talk about their findings and what they mean.	Students should be able to answer the questions on the worksheet and verbally explain what their findings mean. They should be able to accurately tell the instructor and the fellow students what probability means and how it relates to the activity. Students should also be able to explain if using the technology made the lesson easier or	Students should be made aware that the worksheets will be turned in at the end of class to the instructor.

	test without studying and merely guessing?" The students will give their findings to the instructor and be able to see what other students found. Take out The instructor will then ask the students to get into groups of two or three. The groups will then answer the questions on the worksheet about the activity and their findings. The instructor will then hand out a set of questions for the class to answer individually. This will serve as a closing for the lesson.(attachment B)		more difficult.	

Evaluation (Assessment): The teacher will have the students work in small groups to answer several questions about the lesson. This will allow the instructor to accurately assess the students understanding of probability through the use of technology and the written application of their knowledge.

TI Group Handout: Modified from a worksheet retrieved from
http://education.ti.com/educationportal/activityexchange/Activity.do?aId=4254
Included with permission (see below).

You're Probably Right, It's Wrong

Nathan had a choice between studying for a mathematics test and going to the movies with a friend. He knew going to the movies was the wrong choice, but he decided to go anyway. When the mathematics test was handed out the next day, he knew he should have studied. After seeing the test, it was clear that he was not prepared to take it. Nathan was somewhat relieved when he saw that the test had 20 multiple-choice questions. He knew that if he guessed the answers, he would have a 25% chance of getting the correct answer for each question, since each question had four choices. Nathan remembered that his TI-83 Plus had a random number generator. He used this feature to help him guess the answers on the test. Nathan is now nervous about the results of the mathematics test. If he fails this test, he will be grounded for a month. Nathan thinks that he did not pass the test. Is he right?

<u>Clearing your screens and turning of Stat Plots</u>

1. Turn off STAT PLOTS
2. Make sure you Y= is clear
3. Make sure your MODE and FORMAT are set to the defaults.
4. Clear all Lists. Added this step

<u>Random Number/Integer Generator</u>

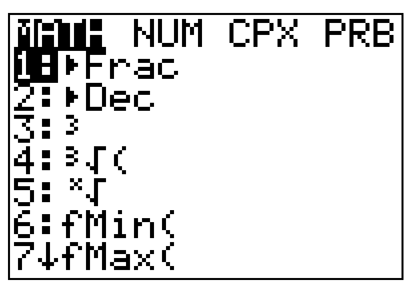
Now, we are going to randomly generate a list of answers just as Nathan did.

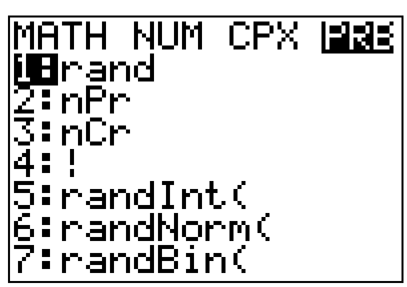
The following steps will generate a list of random numbers between 1 and 4 and store them in **L2**.

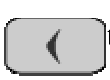
1. 

Quit

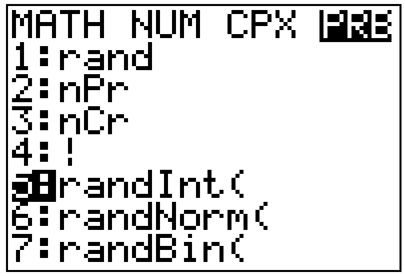
2. Press 



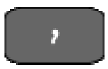


3. Press  to move cursor to the **PRB** Menu

4. Select **5:randInt(**

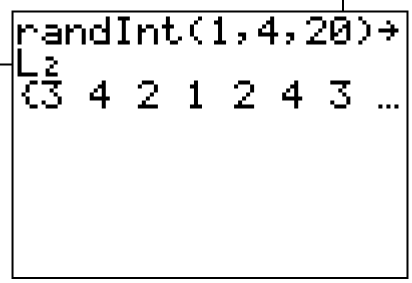


5. This is what your screen should look like.

6. Press 1  4  20 

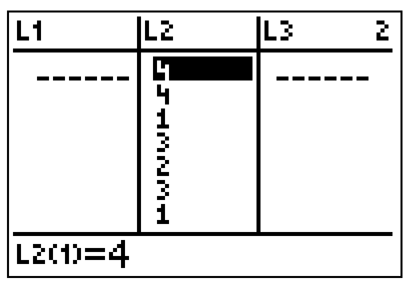
[L2] 

These numbers represent the answers that Nathan used on the test.



Your generated list may not look like the person next to you…this is your calculator's uniquely generated list.

It should look like this in your list



<u>The correct answers to the test</u>

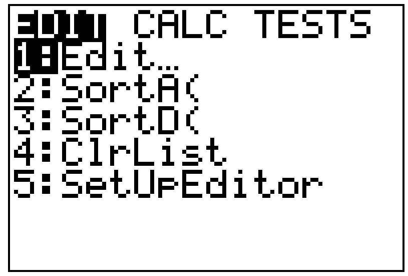
The correct answers to the test are:

1. C - 3	6. C - 3	11. B - 2	16. C - 3
2. B - 2	7. A - 1	12. A - 1	17. D - 4
3. C - 3	8. B - 2	13. A - 1	18. D - 4
4. D - 4	9. D - 4	14. D - 4	19. C - 3
5. D - 4	10. C - 3	15. D - 4	20. A - 1

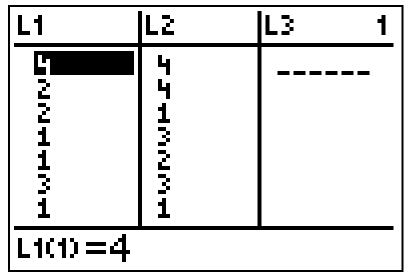
Enter these into L1

Press STAT and select **1:Edit** by pressing ENTER

And enter the data from above

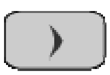
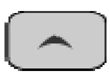


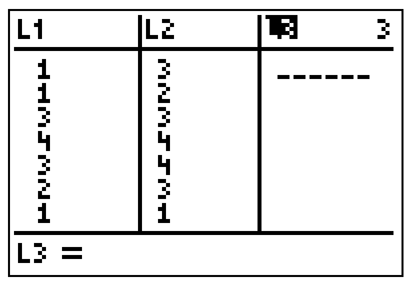
Your list/screen should look something like this



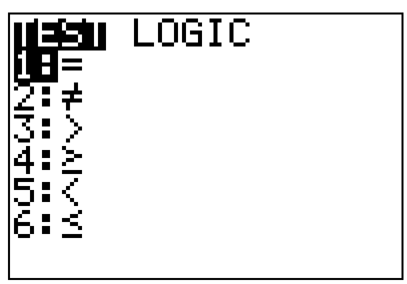
<u>**Compare Right or Wrong**</u>

Compare your answers with the correct answer for the test. Using the equal sign, compare the number in L1 to the corresponding number in L2. If the two numbers are equal, the TI-83 Plus returns a 1, which indicated that the statement is true. If the numbers are not equal, the TI-83 Plus returns a 0, which indicates that the statement is false. Follow the steps to perform this operation.

1. Press   to highlight L3

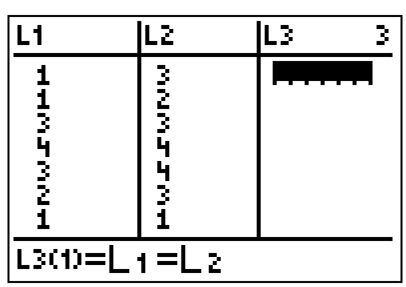


2. Press 2nd [L1] 2nd [Test] to display the **TEST** menu

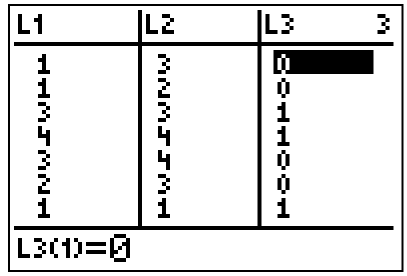


3. Press ENTER to select and paste the equal sign in the function.

4. Press 2nd [L2] .



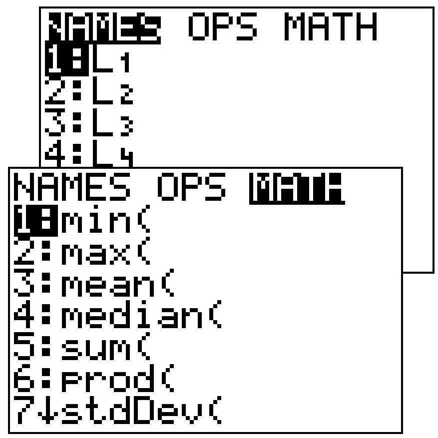
5. Press ENTER to see the comparison with the The correct answers.



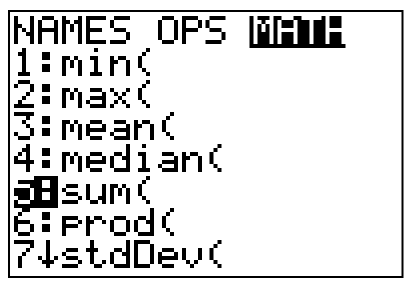
To find the number of correct answers in the simulation, find the sum of the numbers in **L3**

1. Press 2nd [Quit] 2nd [List] to Display the **NAMES** menu.

2. Move the cursor to the **MATH** menu.

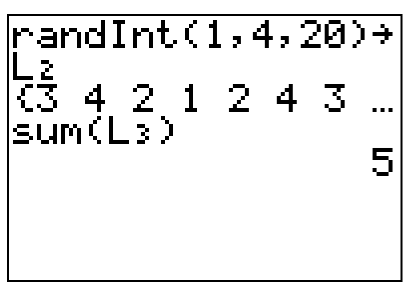


3. Select **5:sum(**



4. Press 2nd [L3])

5. Press ENTER



Each time you run the number (answer) generator the calculator will generate a new list of answers.

Now run the number generator and the sum generator two (2) more times, and record your answers.

1. _____

2. _____

3. _____

Please answer the following questions.
After lesson Question:

1. Do you think it is a good idea to use a random number generator to answer the multiple-choice questions on a test? Explain.

____

____

2. What where you able to derive from this lesson?

____

____

3. Was the handout easy to follow?

____

____

4. What changes would you make to the lesson if you were to teach the lesson?

____

____

5. Was this lesson made easier or more difficult through the use of technology? Explain

____

____

Permission to include from TI.com.

Cavin, Rose

From:	TI Cares Customer Support [ti-cares@ti.com]	**Sent:**	Mon 9/24/2007 6:28 PM
To:	Cavin, Rose		
Cc:			
Subject:	Re: US, EdPrograms, Other [REF:17352014301]		
Attachments:			

Dear Rose,

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You inquired regarding the usage of activities from our Activity Exchange website. It sounds like you and your colleague have made excellent use of the materials available from this site. You are using them exactly as intended. As long as you give credit as due then you should have no worries. Here is a link to guidelines on use of our copyrighted materials:

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If you have questions in the future, feel free to send me an email. You can always visit the Texas Instruments Knowledge Base for around the clock solutions to your questions.

http://support.education.ti.com

Sincerely,

Sarah Scott

Texas Instruments

Email: ti-cares@ti.com
General Information: (800) 842-2737
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http://www.cabrijr.com/

---- Original Message ----
Name: Rose Cavin
Country: US
Type of Service: EdPrograms
Product Group: OtherGroup
Product: Other
Purchase Date: nomonth/noyearselected
Customer Type: EdCollege

XL group Lesson Plan

Group Members: Scott, John, Margie

Date lesson will be taught:

Time lesson will begin:

Classroom Teacher Name:

Brief description of the class:

Hour and Location:

Goal of the Micro-Teaching Lesson Study Group: To engage the students in exploring mathematical patterns and/or relationships using technological tools to develop a rich understanding of mathematical topics.

Lesson Information

Title of the lesson: Credit Cards – Worth it or Not

Goal(s) of the lesson:

1) Teach students how to write formulas in Excel to see the affects of interest on the ending balance.
2) Students will be able to see the relationship in the change between the monthly payments and the ending balances.

How this lesson is related to the overarching lesson study goal: Through Microsoft Excel, the students explore the relationships between interest and ending balance with credit cards. This lesson focuses on finding ending balances and interest by creating formulas. If time allows, students will examine the graphical aspect of the data.

How this lesson related to the curriculum: College Algebra involves two variable equations as does this lesson. (An interest function is a two variable function.)

Process of the study lesson:

Steps of the lesson: learning activities and key questions (and time allocation)	Student activities/ expected student reactions or responses	Teacher's response to student reactions / Things to remember	Goals and Method(s) of evaluation	Notes

I. Introduction to lesson – Overview of some key points: No calculators, Work together, Use F4 for $, Equation starts with equal sign, Read direction, You CAN do this. (7-9min)	Students will be asked to log on. Students will be given handouts with directions that they will need to follow. Before beginning the actual lesson, students will be asked to save the document.	Some students may not know how to log on, so they will be shown how to log on. The handout gives students directions on how to save. Some students still may have trouble doing this. The teacher will help when necessary.	Students will have the appropriate Excel document opened and saved. This will be verbally and visually assessed.	Students will be given the handout when they come in. It would be a good idea to use the projector screen to show the students how to do the first few steps.
II. Students will begin the lesson according to handout. Students will need to create formulas to find out how out the balance left on the card at the end of the year. (10-15min)	Students will find the credit card information they need on the handout. Information for inserting formulas into Excel can be found on the handout. Students may have trouble creating the correct formulas and placing them in the correct spots.	Specified cells will turn green if the students have entered the information in correctly. Periodically stop and make sure that everyone understands how to do the lesson. Use the projector for demonstration.	Students will create appropriate formulas and place them in Excel. All cells will turn green if the students get the answers correct.	If you run out of time, go to questions 28 and 29. Make sure that students turn in handouts before leaving. Students may get a copy of handout from Mrs. Cavin if they wish to complete the assignment at a later date.
III. (This section is for going further if time allows.) Students will use the information that they have obtained to answer questions on the handout. Students will determine the total amount of interest paid in the first year.	Students will determine the how to find the answers. They should be able to do this based on what they have learned up to this point. Students might automatically put in a new monthly payment instead of actually predicting.	If students do automatically put in a new monthly payment without actually making a prediction, they still will have to answer the question asking why it changed. Students should still be able to explain why the ending balance changes.	Students will be able to use what they just learned to answer questions. Students will be able to see the relationship in the change between the monthly payments and the ending balances.	Remember to give the students the appropriate time to complete the questions and share their answers with the class. If time permits, asks students what kind of

Students will determine how long it will take to pay off the credit card. Students will determine how much they would owe at the end of one year if they did not have to pay interest. Students will predict the balance after one year if the monthly payment changes.(17-20min)			Students will share their answers with the class.	regression line the data creates. Remember that the line is not quite linear.

III. Evaluation (Assessment)

The last portion of the handout contains the following questions which assess what they have learned.

22. Write down your ending balance for the first year. ________________
23. Using what you have learned, determine how long it would take to pay the credit card off completely. Place your answer here. _________________
24. How much would you owe at the end of the first year if you did not have to pay interest? _________________
25. Based on everything that you have just learned, do you think it is worth it to buy that laptop on a credit card? Why or why not? (Be sure and compare the ending balances from questions 21 and 23.)
26. Predict the balance after 1 year if the monthly payment was fifty dollars.
27. Try entering the fifty dollar monthly payment in cell B3. Was the answer the same as your prediction in question 22? Why or why not?
28. Was the technology you used in this lesson beneficial? Why or why not? If you could change anything about this lesson, what would it be?

XL Group Lesson Handout: Credit Card Interest

Almost everyone knows about credit cards. You can charge $1,000.00 for the low monthly payment of $25.00 per month. If you knew you would be paying for that new laptop for the next 10 years, would you take the leap and buy on credit?

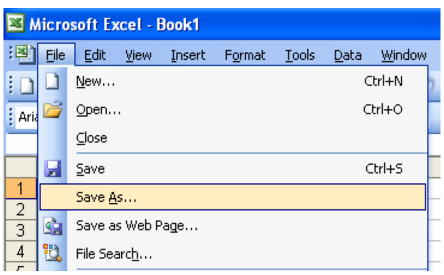
The goal of this activity is to help make you aware of the cost of credit.

1. Log on at a computer.

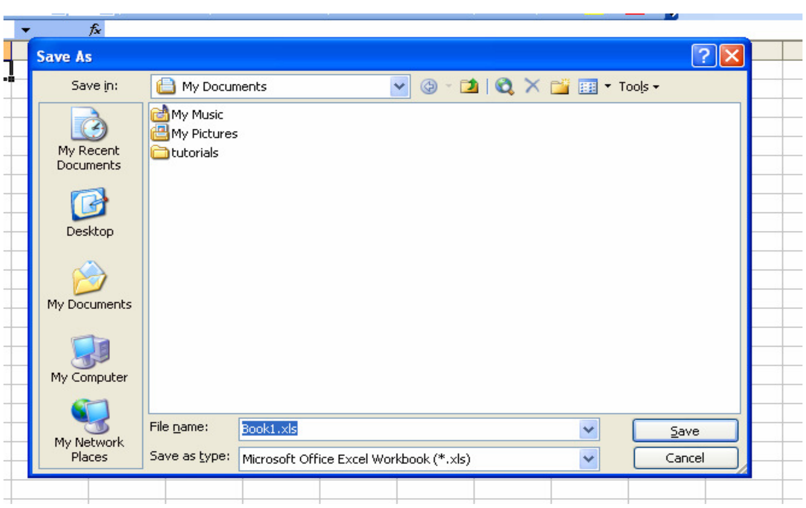
2. Open **Microsoft Excel**. Open the menu, **Tools/Macro/Security**. On the **Security Level** tab, select **Medium**. Select **OK**.

3. Select the **File** menu, then **Open**. Browse to "**exchange2\education\eme3410**".

4. Open the Excel document, "**Credit Cards – Worth it or Not**". Save this document as "**my documents\book1.xls**".



5. The following box should appear on your screen. If it does, left click on "**Save**". If the screen does not appear and you are unsure how to save, please raise your hand.



6. At the bottom left corner of the window, click ***sheet 2*** to ensure it is in the foreground.

7. Assume that you are charging $1000.00 to a new credit card. The Annual Percentage Rate (APR) on your card is 9.90%. Your monthly payment is $25.00. Determine how much money you will have left on your card at the end of the first year. Begin by placing the beginning balance in B1 of your Excel document. If you place the correct value in the cell, it will turn green and you may move to the next step.

8. In B2, place APR value. It can be a decimal or percent value. If you place the correct value in the cell, it will turn green and you may move to the next step. If at any point you have trouble, please raise your hand.

9. The class will do this step together! You know what the APR value is. Now you need to determine your monthly interest rate. In C2, create a formula to determine the monthly interest rate for your credit card. (To create a formula, select the cell where you want the formula. Press "=" on your keyboard. In this case, you will divide the APR by 12. Therefore, you need to select the cell with the APR value in it first. Next, press the "/" sign on your keyboard. Then, enter "12". Finally, press enter.) If the value in the cell is correct, it will turn green and you may move to the next step.

10. In B3, enter the amount of your monthly payment.

11. In B6, enter your beginning balance. From now on, if you place the correct value in a cell, it will turn green and you may move to the next step.

12. With this credit card, you will not pay interest for the first month, so enter the appropriate amount in C6.

13. In D6, you will need to show your monthly payment. Since you have already entered the amount of your monthly payment on this sheet, this will be easy. First, press "=" on your keyboard. Then, left click on the cell which contains the value you want to use. Once you have done this, use the mouse to move your cursor in front of the first letter. Press F4. Dollar signs should appear in front of the letter and number. This tells Excel to always use this cell. Now press enter.

14. Left click once on D6. Move your cursor over the bottom right hand corner until you get a black "+". While you have the black "+", left click. Hold down and drag the formula all of the way to December then let go. The monthly payment column should now be filled.

15. Now you will need to determine the ending balance for the month. In E6, enter the appropriate formula by linking it to cells in your document. (Hint: You must press "=" first. Your formula should look similar to =(B+C)-D. You will not need to use dollar signs. You may left click on the cells you want to use in your formula.)

16. In B7, you will need to show your beginning balance for the month of February. You should do this by left clicking on B7, pressing "=", and then selecting the cell with the appropriate value. Once you have done this, press enter.

17. Now that you have the correct formula for B7, you need to drag the formula down through B17 just like you did in step 13.

18. Now you will need to figure out how much interest has been added to your card during the month of February. You will enter a formula in C7. (Hint: You will want dollar signs in front of your interest rate.)

19. To calculate the interest for the first year, you will need to drag the formula from C7 all of the way down to December. You will do this just as you did in step 13.

20. Now that you have the needed information for the month of February. You will need to drag the formula from E6 just like you did in step 13.

21. Now see if you can find out how much total interest you had to pay in one year. You will need to enter a formula in a cell. Decide which column you want to find the sum of. In a cell of your choosing, enter "=sum(", drag over the column you want to sum and then place a ")" before pressing enter. Write your sum here. _______________

22. Write down your ending balance for the first year. _______________

23. Using what you have learned, determine how long it would take to pay the credit card off completely. Place your answer here. ________________

24. How much would you owe at the end of the first year if you did not have to pay interest? ________________

25. Based on everything that you have just learned, do you think it is worth it to buy that laptop on a credit card? Why or why not? (Be sure and compare the ending balances from questions 21 and 23.)

26. Predict the balance after 1 year if the monthly payment was fifty dollars.

27. Try entering the fifty dollar monthly payment in cell B3. Was the answer the same as your prediction in question 22? Why or why not?

28. Was the technology you used in this lesson beneficial? Why or why not?

29. If you could change anything about this lesson, what would it be?

APPENDIX K

MICROTEACHING LESSON STUDY FEEDBACK SURVEY

Adapted with permission from M. Fernández (2005).

Member Name:

Group:

You may find it helpful to read through the entire survey before responding. Some of the questions overlap in content.

(1) Group collaboration during the Micro-teaching/Lesson-study Project:

(a) Give a brief description of how your group developed the strategies to be used in the presentation of your lesson.

(b) Describe the specific considerations that affected how your group decided upon the technological tool to be used in the presentation of your lesson.

(b) What role did each individual play in the development of the lesson, including any modifications made after the first and second presentation? Indicate names as needed.

(c) What did you do when you met together as a group? Include approximately how much time you spent as a group, including the review of the lesson.

<u>**For each of the following circle one of the ratings and explain your reasoning for the selection you made.**</u>

(2) Using the Lesson Feedback Forms was helpful in identifying strengths and weaknesses of the lesson.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Explain:

(3) Analyzing each others' teaching of the lesson helped me think more deeply about my own teaching.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Explain:

(4a) Feedback from my group members helped me understand my teaching strengths and areas for improvement.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Explain:

(4b) Feedback from my group members helped me understand the strengths in our lesson and areas for improvement.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Explain:

(5) When I analyzed others lessons, my concern for their feeling influenced my assessment and feedback.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Explain:

(6) I was upset by the feedback I received from my peers on my microteaching.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Explain:

(7a) Planning together with my group members helped me understand ways of using technology in teaching.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Explain:

(7b) The actual teaching of the lesson helped me understand ways of using technology in teaching.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Explain:

(8a) Planning together with my group members helped me broaden my knowledge of the topic we taught.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Explain:

(8b) The actual teaching of the lesson helped me broaden my understanding of the topic we taught.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Explain:

(9a) Preparing together with my group members helped me understand teaching in a student-centered environment.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Explain:

(9b) The actual teaching of the lesson helped me understand teaching in a student-centered environment.

Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree

Explain:

Learning to teach with technology involves three basic components: The content area, the teaching strategies (pedagogy) and the technological tool itself. The next set of questions deals with these three areas.

(10) What did you learn about your content area while developing and teaching the lesson? Be specific.

(11) Did you enhance your understanding of the lesson content from:

(a) the first teaching of the lesson to the second teaching of the lesson? Why or why not?

(b) the second teaching of the lesson to the third teaching of the lesson? Why or why not?

(12) What did you learn about teaching strategies while developing and teaching the lesson? Be specific.

(13) Did you enhance your understanding of teaching strategies from:

(a) the first teaching of the lesson to the second teaching of the lesson?
Why or why not?

(b) the second teaching of the lesson to the third teaching of the lesson?
Why or why not?

(14) What did you learn about the use of technological tools while developing and teaching the lesson? Be specific.

(15) Did you enhance your understanding of the use of technology in teaching from:

(a) the first teaching of the lesson to the second teaching of the lesson?
Why or why not?

(b) the second teaching of the lesson to the third teaching of the lesson?
Why or why not?

(16) Please add any other suggestions, comments or feedback you feel would be useful in future applications of the micro-teaching/lesson-study approach to developing skills related to teaching with technology.

Thank you for taking the time to complete the survey. Your feedback is greatly appreciated!!

APPENDIX L

FINAL INTERVIEW PROTOCOL

Note: Some questions on the original final interview protocol were addressed adequately in the final surveys. Those questions removed from this verbal interview protocol.

TI group

Thank you for coming in today. I have looked over your final survey and would like to ask you some questions related to your work during the semester and to clarify some feedback you provided on that survey. So let's get started.

1) Please describe in your own words the objective of your group's lesson.

2) The purpose of my research to explore technological pedagogical content knowledge. Please define for me in your own word technological pedagogical content knowledge.

3) I have one more general question; please define your concept of "math".

Feedback/Questions for the TI group from the survey:

4) All members:

a) Were you familiar with this command on the calculator before this project?

The sum command? The random command? The test command?

b) Do you think the students knew these commands before the lesson?

c) In your group's lesson plan it was stated that the teacher would work through one simulation with the group while the group watched, and then let them work one on their own. None of you worked one while they watched. I just wondered if there was a reason for that?

d) In using TI-SmartView, several of you had different screen images displayed. I wondered if there was a specific reason for that.

5) Individuals members:

Todd:

a) You used a PowerPoint presentation and neither of the others did. Was there a specific reason for that?

b) In your session you had the students read aloud and neither of the other did. Was there a specific reason for that?

c) I have a few responses from your final feedback form that I would like some clarification on.

Page 2: You said this several times in your final feedback. I wish I could have played a more effective role. Can you expand on that?

Page 2: In response to the question that the feedback forms were helpful in identifying strengths and weaknesses of the lesson, you said “the feedback forms were ok but I learned a lot in the group meetings and watching the videos of the lessons.” Did you think the feedback forms were not helpful?

Page 4 – In response to “the actual teaching of the lesson helped me understand ways of using technology in teaching” your comment was “Teaching the lesson gave me insight on how helpful TI-SmartView can be.” What did you learn? How helpful can it be?

Page 5 – You talked about whole class instruction and small group instruction in your teaching strategies and that small group is better for classes that the students are at different levels. Can you expand on that for me?

Page 7 - You indicate that you felt working in a microteaching lesson study group "subtracts from one's own teaching style, and individuality." Please explain how and why you think this happens.

(To general questions)

Chloe:

a) On the feedback forms from the students you taught, several of them say that the calculator is doing all the work. What do you think about that?

b) I noticed that you made a change in your teaching strategy from Todd's. He had them read the directions aloud and you did not. Why did you do that differently?

c) I have a few responses from your final feedback form that I would like some clarification on.

Pages 3 & 4 - On your final survey, two questions related to the use of the technology. The first indicated that "I am not sure that planning with my group helped me understand the technology. I am familiar with the 83 and could perform the technology as part of this lesson.” And the second said, “I learned to lecture using the technology. For instance time management is crucial when teaching with technology. I had to do several things at one time because different students with different levels of understanding worked at different paces. In terms of the actual technology, I learned more about the calculator and had a nice review of functions that I already knew.” There seemed to be a little contradiction here. Would you please expand on these two statements?

Page 4 - In response to "The actual teaching of the lesson helped me broaden my understanding of the topic we taught" you stated, “Teaching the lesson certainly helped me to broaden my understanding in terms of how students respond and how students understand. I learned that although I understand it, explaining it was a whole different ball game and created a need to find other ways to verbalize the topic." Please expand on this for me.

Page 5 - You stated that "Cooperative learning is not always the best option." When do you think it is and when do you think is it not?

Page 7 - You talked about the experience of working in a cooperative group and your two responses were very different. What did you think about the experience of planning and teaching this lesson as a *group* activity?

(To general questions)

Beth:

a) I have a few responses from your final feedback form that I would like some clarification on.

Page 2 - You indicated that you did not need the feedback forms to see the strengths and weaknesses in the lesson. How did you identify the strengths and weaknesses?

Page 3 – You stated that "By teaching the lesson and watching my team members teach the lesson I was better able to use the technology." How were you better able to use the technology? What did you personally gain about the technology?)

Page 3 – You stated, you were "able to further my knowledge of the topic of the lesson." What knowledge did you gain about the topic?

Page 4 – You also stated that you "learned some different things about teaching styles." Please expand on what you learned about teaching styles.

(All group members). I have a few more general questions now that are not related directly to your personal feedback.

6) If you could start the lesson over, would you select a different technology? Why or why not? (This was changed to: If you could do your lesson over again in a perfect world, what would you do different?)

7) In several places, several of you stated something like, "The technology was used to do the math." What do you think is meant by this? (Possible follow ups)

    Define "math" (if not done in a prior question).

    What is the technology doing?

    Is it required that the students do the "math" first?

8) In setting up micro-teaching and lesson-study experiences for future students enrolled in this course,

    a) What one thing would you suggest I take out of the process?

b) What one thing would you NOT take out of the process?

Thank you very much for clarifying these things, and for helping me with the project.

XL group

Thank you for coming in today. I have looked over your final survey and would like to ask you some questions related to your work during the semester and to clarify some feedback you provided on that survey. So let's get started.

1) Please describe in your own words the objective of your group's lesson.

2) The purpose of my research to explore technological pedagogical content knowledge. Please define for me in your own word technological pedagogical content knowledge.

3) I have one more general question; please define your concept of "math".

Feedback/Questions for the TI group from the survey:

4) All members:

a) Can you give me your definition of student-centered learning?

b) Was it important to you that the cells turned green? Why?

5) Individuals members:

(All group members). I have a few more general questions now that are not related directly to your personal feedback.

John:

a) On one of your feedback forms you indicated that the students were not reading the directions carefully. You mentioned particularly step 8. But if you read step 8 on the handout it says the class will do this step together. Do you think that might have created a problem for the class?

b) On the feedback to Margie's lesson, the question says "How did the changes help engage students in learning mathematics with technology." You said: "By working the first part with the students the teacher was able to open up the comprehension gap. Once the students discovered what they were doing the students wanted to learn how to do the activity their selves. By opening up the class to working in groups the students were able to compare their findings with their friends' findings." What do you mean here by open up the comprehension gap?

c) From the final survey:

Page 1 – You indicated that "we decided first upon the lesson that we wanted and the material that we wanted the students to get out of the lesson. Then, we considered the best way to present the information in a way that will be easy for the students to understand." Do you remember what you discussed? What might have influenced the decision?

Page 3 – You indicated neutral on the question that "the actual teaching of the lesson helped me understand way of using technology in teaching." Can you explain the reason for the neutral response?

(On to general questions)

Scott:

a) On the Excel file you used in your lesson you added a background. Did you have a special purpose in doing that?

From feedback forms:

In one of your feedback forms you indicated that Excel was used to graphically display credit card data. What did you mean by graphically?

You indicated that you focused on getting the spreadsheet to work correctly. What do you mean yb "correctly?"

Your feedback on content indicated that you learned about other methods of credit card balance. Can you give me some examples?

You responded to the question "What did you learn about the use of technological tools while developing and teaching the lesson? Be Specific." with the comment, "Use excel instead of TI-Interactive?" Can you explain why you felt this way?

You indicated that knowing the technology is just as important as knowing the content. Without knowing the technology you can't present your content. Can you expand on this statement?

(On to general questions)

Margie:

a) You indicated one of the things you liked about Excel is that you could make the document more interactive. Can you expand on that?

b) You indicated that some of the students got caught up in trying to figure out how to use the technology and missed the part of the lesson objectives. What part of the objectives did they miss?

c) You stated that you were not sure that planning with your group helped to understand ways of using technology in teaching. Do you still feel this way?

d) When asked about teaching strategies you said you did really focus on learning specific strategies but you had the students work in group. I wondered if you felt you learned anything about students working in groups?

(On to general questions)

6) If you could start the lesson over, would you select a different technology? Why or why not? (This was changed to: If you could do your lesson over again in a perfect world, what would you do different?)

7) In several places, several of you stated something like, "The technology was used to do the math." What do you think is meant by this? (Possible follow ups)

   Define "math" (if not done in a prior question).

   What is the technology doing?

   Is it required that the students do the "math" first?

8) In setting up micro-teaching and lesson-study experiences for future students enrolled in this course,

   a) What one thing would you suggest I take out of the process?

   b) What one thing would you NOT take out of the process?

Thank you very much for clarifying these things, and for helping me with the project.

APPENDIX M

CODING SCHEME

<table>
<tr><td colspan="3">Coding Scheme for the TPCK Framework – Modified from Cavin (2006a)
Technology, Pedagogy and Content Knowledge
(Drawn from State and National standards as identified below)</td></tr>
<tr><td>Technology – T
Indicated when the preservice teacher will:</td><td>Pedagogy – P
Indicated when the preservice teacher will:</td><td>Content – C
Indicated when the preservice teacher will:</td></tr>
<tr><td>T1. Navigate the system (NS1)
T2. Communicate electronically (NS5)
T3. Use technology tools on a personal basis (F12)
Tx. To be added as needed</td><td>P1. Practice techniques which accommodate student differences (F1)
P2. Plan activities that engage students in learning activities (F10)
P3. Recognize the need for learner-centered environments (F12)
Px. To be added as needed</td><td>C1. Use numbers and operations (N)
C2. Exhibit algebraic manipulation (N)
C3. Perform data analysis (N)
C4. Calculate probability (N)
Cx. To be added as needed</td></tr>
<tr><td colspan="3">To identify the overlap of the three basic components, the following categories were added to be used in coding PC, TC, TP, and the overarching TPC(K).</td></tr>
<tr><td colspan="2"><u>Pedagogy and Content - PC</u>
PC1. Be aware of inter-relationship of topics (N18, N21)
PC2. Use previously acquired knowledge to link new ideas (F7)
PC3. Plan and conduct collaborative lessons with colleagues (F8, F10)
PC4. Maintain academic focus of students by use of varied motivational devices (F9)
PC5. Communicate knowledge of subject matter in a manner that enables students to learn (F8)
PCx. To be added as needed</td><td></td></tr>
<tr><td></td><td colspan="2"><u>Technology and Pedagogy - PT</u>
TP1. Facilitate technology-enhanced experiences that address content standards and student technology standards (NT3)
TP2. Use technology to support learner-centered strategies that address the diverse needs of students (NT3)
TP3. Apply technology to develop students' higher order skills and creativity (NT3)
TP4. Identify technology productivity tools to assist with management of student learning (NT3, F12)
TP5. Teach students to use available computers and other</td></tr>
</table>

<table>
<tr><td></td><td colspan="2">forms of technology (F12)
TP6. Arrange and manage the physical environment, including technology, to facilitate student learning outcomes (F9, N18)
TP7. Recognize problem solving as a valued individual skill that can be amplified through the use of technology (NS6)
TP8. Demonstrate awareness of and model acceptable use policies and copyright issues (F12)
TPx. To be added as needed</td></tr>
<tr><td><u>Technology and Content - TC</u>
TC1. Use technology in material preparation (F12)
TC2. Use technology tools to process data and report results. (NS5)</td><td></td><td><u>Technology and Content - TC</u>
TC3. Use digital information obtained through intranets and/or the internet (e-mail, research, etc) in lessons (F12)
TCx. To be added as needed</td></tr>
<tr><td colspan="3"><u>Technology and Pedagogy and Content – TPC</u>
TPC1. Use the materials and technologies of the subject field in developing learning activities for students (F8)
TPC2. Identify strategies, materials, and technologies to expand students' mathematical thinking abilities (F12)
TPC3. Assist students in using the technological mathematical resources available to them (F10)
TPC4. Select and utilize educational software tools for instructional purposes in mathematics (F12)
TPC5. Select or create mathematical tasks that take advantage of what technology can do efficiently and well (N26)
TPC6. Reflect on the use of technology in presenting the topic and make modifications as needed (N17, F3)
TPCx. To be added as needed.</td></tr>
</table>

Source:

Na: Taken from NCTM (2000) where “a” indicates a page number when appropriate.
Fa: Taken from FDOE (2003) where “a” indicates the specific accomplished practice.
NTa: Taken from ISTEa (2000) where “a” indicates the specific NETs-T standard.
NSa: Taken from ISTEb (2000) where “a” indicates the specific NETs-S standard, which are included in NETs-T standard 1.

APPENDIX N

CORRELATION OF DATA SETS WITH RESEARCH

Coded Data Sets	Source	Research question(s) addressed
Audio recordings – lesson development	TI and XL group meetings	What changes in TPCK occurred; factors and barriers
First lesson feedback forms	Individual group members	What changes in TPCK occurred; factors and barriers
Audio recordings – first lesson modifications	TI and XL group meetings	What changes in TPCK occurred; factors and barriers
Second lesson feedback forms	Individual group members	What changes in TPCK occurred; factors and barriers
Audio recordings – final lesson modification	TI and XL group meetings	What changes in TPCK occurred; factors and barriers
Survey feedback of the MLS process	Individual group members	What changes in TPCK occurred; what aspects of MLS afford opportunities for the changes in TPCK; factors and barriers
Final interview	Individual group members	What changes in TPCK occurred; what aspects of MLS afford opportunities for the changes in TPCK; factors and barriers

Un-coded Data Sets – used for triangulation	Source
Biographical data surveys	Individual group members
Task based interviews	Individual group members
Video recordings lessons	Individual group members
Fieldnotes	Researcher observations
Teachee feedback forms	Individual teachees

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BIOGRAPHICAL SKETCH
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Education:
Doctor of Philosophy
Mathematics Education
Florida State University
Tallahassee, Florida
December, 2007

Post Masters Work
29 Graduate Math Hours
Troy State University
Dothan, Alabama

University of West Florida, Pensacola, Fl.
Masters Degree, Curriculum and Instruction
Graduated August, 1986

Florida State University, Tallahassee, Florida
Bachelors of Science, Math Education
Graduated Summa Cum Laude, 1975

Employment History:
Chipola (Junior) College – 1996 – Current
- Teaching duties: Intermediate Algebra, College Algebra, Trigonometry, Pre-Calculus, Liberal Arts Math, Teaching with Technology, Classroom Management
- Other duties: Supervise the Math Lab, Co-develop a data entry program to track student progress
- Committees: Chairman of Chipola Council of Educators, and as a member of the Governance Council, Curriculum committee, Technology committee, Honor's committee, Staff and Program Development committee, and Institutional Planning and Accountability committee. Co-sponsor of the Brain Bowl team and Mu-Alpha-Theta.

Marianna High School - 1986 to 1996
- Teaching duties: College Trigonometry, analytic geometry, geometry honors, Algebra I Honors, Algebra I, Applied Math I and II, high school competency skills, computer programming in BASIC and Pascal
- Other duties: Math department chairman, Beta Club sponsor, National Honor Society sponsor, Math competition team sponsor
- Committees: School improvement team chairman, , technology committee member

Marianna Middle School - 1982 to 1986
- Teaching duties: 7th and 8th grade math

Other duties: Jr. Beta Club sponsor, 8th grade chairman, Math competition team sponsor
Committees: Instructional council member

Alford Elementary School (K-8) - 1979 to 1982
Teaching duties: 6th, 7th, and 8th grade math, 8th grade consumer education, 8th grade science, 8th grade social studies
Other duties: Jr. Beta sponsor

Cottondale High School – 1979
Teaching duties: Math compensatory education

Florida State University - Office of Contracts and Grants - 1975 to 1978
Duties: Maintained a data base of contracts and grants awarded to the University Florida State University

Florida State University - Computing Center - 1972 to 1975
Duties: Computer systems programmer

Research:

Supervised Research Project – 2006 – Developing Technological Pedagogical Content Knowledge in Preservice Math Teachers – Dr. Maria Fernández

Thesis – The effect of content on the problem solving skills of 8th grade math student

Awards and recognitions:

Recipient of the Louis Bender Scholarship – FSU – 2005-2006
Recipient of the Kirkland Award for teaching excellence – 2003-2004
Faculty/Administrator of the Year – 2001-2002
Jackson County Teacher of the Year - 1990-91
Outstanding Young Educator nominee - 1985 - Marianna Middle School
Recognized as Associate Master Teacher - Department of Education - 1984
Who's Who Among American Teachers nominee
Jackson County representative - Committee to write minimum performance standards in computer education
Chairman - Education Committee - Marianna Jr. Woman's Club
Recipient - two C.O.A.S.T.A.L. grants and one Tech Prep grant

Professional memberships:

Association of Mathematics Teacher Educators
National Council of Teachers of Mathematics
Florida Council of Teachers of Mathematics
International Society for Technology in Education

Workshops/training sessions attended:

Society for Instructional technology and Teacher Educaiton – March 2007 – Presented a full paper on the dissertation pilot study: Developing Technological Pedagogical Content Knowledge in Preservice Math and Science Teachers

Association of Mathematics Teacher Educators – January, 2006
Florida Faculty Institute, Daytona, Summer 2003
T^3 (Teachers Teaching with Technology), 1998, 2002
ICTCM – Technology Conference – Spring 2000, Spring 2001

Web Page Development – Fall 1999
Using technology in the classroom - JAAT - Summer 1995 - included Firn, PowerPoint, and Linkway
Authentic Assessment
Onward to Excellence
Beginning Teacher Program - supervisor training
Capital Area Space Orientation - Washington D.C. - through University of Alabama and Chipola Junior College
Space Camp - Huntsville, AL - through Chipola Junior College
Lego Logo - Chipola Jr. College
Turtleometry - Chipola Jr. College
Calculators in the Classroom - Chipola Jr. College
Graphing with the Color Calculator - Miami FL - sponsored by Casio