AN ABSTRACT OF THE DISSERTATION OF

Gogot Suhaerwoto for the degree of Doctor of Philosophy in Mathematics Education presented on April 21, 2006.

Title: Secondary Mathematics Preservice Teachers’ Development of Technology Pedagogical Content Knowledge in Subject-Specific, Technology-Integrated Teacher Preparation Program

Abstract approved:

Margaret L. Niess

The purpose of this study was to describe the development of mathematics preservice teachers’ technology pedagogical content knowledge (TPCK) in a subject specific, technology integrated teacher preparation program. The study also investigated the roles of several influential components of the program and the technology thread throughout the program in supporting preservice teacher development of TPCK. Courses attendances, classroom observations, interviews, questionnaires, classroom artifacts, researcher journal, and preservice teachers’ work samples were gathered to explore the progress of the preservice teachers’ TPCK during a one year program. Three cases of preservice teachers were purposefully selected to describe the development of their TPCK. Each case consisted of three episodes, prior to the program, during the course work, and
During student teaching. Each episode provided the preservice teachers’ description about their TPCK in the context of the program.

The primary finding was that all three preservice teachers showed various degrees of understanding the four components of TPCK: an overarching conception of what it means to teach mathematics with technology; knowledge of instructional strategies and representation; knowledge of students’ understanding, thinking, and learning; knowledge of curriculum and curriculum materials that integrate technology in mathematics. The second finding was that the different understanding of those preservice teachers’ TPCK affected their practices during student teaching. These preservice teachers’ practices of TPCK were categorized into four different levels, accepting, adapting, exploring and advancing. Finally, the study found that the preservice teachers indicated that all the coursework in the program was primarily responsible for the development of their particular levels of TPCK. This finding also provided specific evidence that the technology courses thread in the program was integrated and interconnected throughout the program.

Future research recommendations are included for the investigation of: (1) actions the teacher preparation program needs to take for improving on the different levels of preservice teachers’ TPCK (2) the relationship of the cooperating teachers, university supervisors, and course instructors’ understanding of TPCK on the preservice teachers’ TPCK development; and (3) identification of significant relationships between preservice teachers’ TPCK during the program and their use of technology in their future teaching career.
Secondary Mathematics Preservice Teachers’ Development of Technology Pedagogical Content Knowledge in Subject-Specific, Technology-Integrated Teacher Preparation Program

by

Gogot Suwarwoto

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APPROVED:

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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Gogot Suwarwoto, Author
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CHAPTER I
THE PROBLEM

Introduction

The nation’s schools are faced with hiring two million teachers in this
decade (Hussar, 1999) to replace those retiring or to meet the needs of expanding
enrollments of new students (Feistritzer, 1999; U.S. Department of Education,
1998). From those who graduate and fill up the new positions, only about 20% feel
prepared enough to integrate technology into classroom instruction (Lewis, et. al.,
1999; Archer, 1999). In another survey, only 40% of first-year teachers felt
adequately prepared to integrate technology into their classrooms meaningfully
(Market Data Retrieval, 1999b). Yet, the demands of improving student
achievement and understanding of mathematics through the use of technology have
increased. If students are expected to know more and be able to apply their
knowledge in a meaningful way where technology is available, then teachers must
model the appropriate integration of technology into teaching and learning in their
classrooms. Modeling the appropriate integration of technology requires teachers
not only knowing how to use the technology but also how to teach with the
technology. Consequently, teachers must acquire the knowledge of how to integrate technology into their teaching.

Aside from technology, teaching mathematics requires not only the knowledge of mathematics but also the knowledge of how to teach mathematics. In response to this matter, the U.S. Department of Education (1998) recommends that the teacher education programs provide sequential offerings and emphasize content knowledge as well as pedagogy relevant to teaching a specific subject (known as content-specific pedagogy). Paralleling the importance of knowing what and how to teach mathematics is the issue of providing the preservice teachers with "some mathematics and some pedagogy. In addition to that knowledge," There is much to be learned about mathematics teaching by examining the practice of mathematics teaching as well (Mathematical Sciences Education Board [MSEB], 1996). More specifically, Shulman (1987) defines the knowledge of teaching a specific subject as pedagogical content knowledge (PCK).

Pedagogical content knowledge identifies the distinctive bodies of knowledge for teaching. It represents the blending of content and pedagogy into an understanding of how particular topics, problems or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction. Pedagogical content knowledge is the category most likely to distinguish the understanding of the content specialist from that of the pedagogue. (p. 4)

Knowing mathematics subject matter by itself is insufficient to enable preservice teachers to teach mathematical concepts in a meaningful context that helps students with different learning styles understand conceptually and be able to apply their understanding to real world problems. Each specific subject matter needs specific teaching methods in order to be understood by students in different grades with
different levels of understanding. Therefore, the knowledge of teaching and learning must be part of the preservice teacher program. Those two knowledge bases, (1) subject matter and (2) teaching and learning that describe PCK, include knowledge of the overarching conceptions of what it means to teach a particular subject, curricular materials and curriculum in a particular field, students’ understanding and potential misunderstanding of a subject area, and instructional strategies and representations for teaching particular topics (Grossman, 1988).

Today, technology has become an essential part of our society that everyone, including the education community must learn and incorporate. Even if a school chooses to avoid using technology, students eventually must interact with technology including ways it may impact their eventual work environment. Along with changes in the world and with technology, students in secondary school now must learn mathematics differently than most of their teachers learned 10 or 20 years ago. Technology in today’s mathematics curriculum has become an important tool for helping students learn mathematics. In support of this notion, the National Council of Teachers of Mathematics (NCTM, 2000) states that “technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances learning” (p. 24). Teachers need to learn to teach in different ways that are appropriate for the new learning environment where technologies are included. Knowledge of technology, pedagogy, and subject matter has become an integral part of teacher preparation programs in order to prepare their preservice teachers to teach using technology in their future teaching. In response to this need, “Schools and colleges of education coursework must consistently model exemplary
pedagogy that integrates the use of technology for learning content with methods for working with PK-12 students” (International Society for Technology in Education [ISTE], 2000). In addition to achieving the technological goals, teachers must be prepared for their new roles in a technology-rich environment. The idea of integrating the knowledge of subject matter, teaching and learning, and technology has become apparent today since the needs of students have increased with the enhanced availability and the need to learn with technology. Now the knowledge benchmark that teachers need in order to teach their subject matter with technology is more than just PCK, it needs the development of “TPCK, Technology Pedagogical Content Knowledge.” (Pierson, 1999; Keating & Evans, 2001; Woodbridge, 2004; Niess, 2005).

In mathematics, the case is unique with the growing variety of technologies that can be used for teaching mathematics (e.g., spreadsheets, dynamic geometry software, and graphing calculators). Technologies are evolving on a daily basis. Consequently, it is inadequate to instruct teachers how to use only one specific technology. Instead, teachers must be prepared to make decisions about various technologies, learn new skills for working with them in classrooms, and learn to address many of the pedagogical issues that arise when using technology in teaching, such as the possibility of misunderstanding a concept being taught. Additionally, to support preservice teachers’ technology learning needs, teacher education faculty must model how technology can be used during teaching and assist in the assessment of student performance (CEO Forum, 1999, 2000; Office of Technology Assessment [OTA], 1995; Wetzel, 1993). In conjunction with the
effort of helping preservice teachers, teacher education faculty are encouraged to work together to generate the knowledge about how new teachers learn to integrate and implement educational technology (Schrum, 1999). In response to this suggestion, the National Technology Leadership Retreat (NTLR), representatives of national organizations in mathematics (i.e., NCTM), science (i.e., National Association for Research in Science Teaching [NARST], National Science Teachers Association [NSTA]), social studies (i.e., National Council for the Social Science [NCSS]), English (National Council of Teachers of English [NCTE]), Educational Technology (i.e., AACE, ISTE, Society for Information Technology and Teacher Education [SITE]) and teacher education associations (i.e., Association for Science Teacher Education [AETS], Association for Mathematics Teacher Education [AMTE], American Association of Colleges for Teacher Education [AACTE], the Association of Teacher Educators [ATE], the Center for Excellence in Education [CEE], the College and University Faculty Assembly [CUFA]), have proposed a technology standard for integration of technology in various subjects (Lederman & Niess, 2000). In mathematics education, specifically, the appropriate use of technology for preservice teachers should be introduced and illustrated in the context of meaningful content-based activities, address worthwhile mathematics with appropriate pedagogy, take advantage of the capabilities of technology, facilitate mathematical connections, and incorporate multiple representations of mathematical topics (Garofalo, Drier, Harper, Timmerman & Shockey, 2000).
The emphasis on integrating technology in preservice teacher programs has thus become an essential element in teacher education program topics today. With the goal of assessing teacher education programs’ responses to technology integration, the Milken Exchange on Education Technology commissioned ISTE to survey teacher-preparation institutions across the country. Survey results suggest that these programs increase preservice teachers’ exposure to appropriate education technology if they are to be prepared for today’s classrooms.

Currently, several technology foundation standards for both teachers and students have been developed. ISTE, National Council for Accreditation of Teacher Education [NCATE], Interstate New Teacher Assessment and Support Consortium [INTASC], SITE, and other educational organizations have influenced the policy makers in identifying basic technology foundation standards for teachers. Those organizations have directed their efforts toward increasing the number of teachers who integrate technology in their classrooms and improving the skills of the teachers who already are integrating technology in their classrooms. ISTE has worked to improve teaching and learning by advancing the effective use of technology in K–12 education and teacher education. One of ISTE’s widely accepted contributions has been the National Educational Technology Standards for Teachers (NETS-T) with standards described in six areas:

1. Technology Operations and Concepts,
2. Planning and Designing Learning Environments and Experiences,
3. Teaching, Learning, and Curriculum,
4. Assessment and Evaluation,
5. Productivity and Professional Practice,

These standards direct teachers to be more focused on integrating technology into their classrooms. According to these standards, teachers are expected to use computers in the classroom properly and appropriately according to the level of their students. However, the use of computers in instruction is limited in the classrooms. A report, based on a survey of 1,215 schools with 4,100 teachers of grades 4-12, said that only 11% of mathematics teachers in secondary schools reported using computers in their classrooms on more than 20 occasions during class over roughly a 30-week period (Becker, 2001). In addition, the computer applications that teachers used most often included word processing, CD-ROM references, and skill games. In essence, the major objectives for mathematics teachers in using computer technology have focused mostly on reinforcement and remediation of skills.

**Preservice Teacher Program and Technology**

About 63% of the students who entered undergraduate teacher preparation programs are recent high school graduates (Freistritzer, 1999). Since technology integration has rarely been practiced in their actual classrooms, neither in high school nor middle school, the students who enroll in the secondary teacher preparation programs preparing for teaching mathematics have been taught mathematics with limited technology use and integration. This limitation includes
both the exposure to technology in learning mathematics and the way they understand the mathematics concepts. Typically, technology used in the middle or high school is the graphing calculator with few uses of computers and other technologies in exploring mathematics. Thus, with a limited background of technology skills and knowledge, the new students of teacher preparation programs continuously need to work more with technology courses and technology integration skills in order to be prepared to teach mathematics with technology. At this point, the new students of teacher preparation programs have an essential and important need for their programs to emphasize the knowledge of technology, knowledge of pedagogy, and knowledge of the content of mathematics so that their student teachers graduate with important skills and knowledge for technology integration in their classrooms. This situation requires careful consideration by teacher preparation programs in setting up the curriculum and models for the technology integration they adopt.

Teacher preparation programs play a vital role in preparing future teachers to become proficient in the integration of technology into the curriculum. Teacher preparation programs need to help preservice teachers understand how technology can be used to teach content in rich and meaningful ways (Keating & Evans, 2001). Unfortunately, teacher preparation programs do not currently provide preservice teachers with the kinds of experiences necessary to prepare them to use information technology effectively in their future classroom practice (Duran, 2000; Moursund & Bielefeldt, 1999). A national survey of preservice students and faculty members reveals that preservice students do not receive systematic or
prolonged technology training in their programs (Milken Exchange on Education Technology, 1999).

Being charged with preparing teachers to meet the needs for entering the teaching profession, teacher preparation programs typically have a set curriculum that has been revised and remodeled over the years to meet accreditation standards. Some of those who meet the standards consider that they have the most up-to-date programs. When technology integration in classroom instruction became a standard in some states in order for the preservice teachers to obtain a teaching license, those teacher preparation programs began to incorporate technology work in their programs. The dilemma was and continues to be that it is not easy to remove one, two or more courses and replace them with technology courses. Another concern is that their students need technology course(s) on their transcript in order to receive a teaching license or to transfer to other states.

Initially, the primary mode in which teacher preparation programs have chosen to meet this need was through a separate course in educational technology to be part of the preservice curriculum (Thomas, 1996). This course tended to present technology as an isolated subject, modeling the use of technology as a separate component or “add-on” rather than an integration within the teaching preparation (Jensen, 1992; Novak & Berger, 1991). Consequently, many of those courses failed to adequately prepare teachers for technology integration (Office of Technology Assessment [OTA], 1995). This result is especially true in states lacking specific technology competencies for teacher certification. Therefore, many preservice teachers enter the classroom with minimum exposure to
technology and the techniques for integrating its use into instruction in real world settings (Strudler & Wetzel, 1999). Research shows that technology use has not been central to the preservice preparation experience of most colleges of education. Most new teachers graduate with limited knowledge of the use of technology integration strategies in their daily teaching. Yet, society expects that those preservice teachers are able to integrate technology immediately and effectively in their future teaching after completing their teacher preparation programs even though they have not actually learned how to teach subject matter with technology. Most of the literature on technology integration and preservice teacher education can still be summarized by a comment from 1996:

Most preservice teachers know very little about effective use of technology in education and leaders believe there is a pressing need to increase substantially the amount and quality of instruction teachers receive about technology. The idea may be expressed aggressively, assertively, or in more subtle forms, but the virtually universal conclusion is that teacher education, particularly preservice, is not preparing educators to work in a technology-enriched classroom. (Willis & Mehlinger, 1996, p. 978)

**Problem Statement**

In general, teacher preparation programs have adopted three different models of technology integration: *single course*, *component of courses*, or *integration of technology*. A *single course* model is usually offered by the teacher preparation program to accommodate the need of having a technology course in the program. This model focuses on basic technology skills, such as word processors, email, basic web development, and Internet searches (Hargrave & Hsu, 2000). However, the study strongly suggested that the stand-alone information technology
courses are generally not an efficient way to help new teachers use technology in schools (Moursund & Bielefeldt, 1999). Technology preparation programs that believed that their stand-alone single course on technology was not enough for preparing their preservice teachers to teach with technology have adopted a component of courses model. Therefore, these teacher preparation programs integrated the technology into several method courses related to teaching subject matter. With more than one course, this model has been able to provide the opportunity for their students to not only design lesson plans but also to implement the lessons in a microteaching setting (Pope, Hare, and Howard, 2002). The third model has rarely been adopted in teacher preparation program. This model integrates technology instruction throughout the program. The technology work is offered each term of the program so that preservice teachers have more opportunities to learn by designing and practicing how to teach their subject matter with technology.

Selecting the appropriate model of technology integration has been a challenge for teacher preparation programs. Some considerations for selecting the model include: which forms of the model (single, component of courses, or integration of technology) are most likely to be within the program capabilities; how the model helps the program in meeting the National Educational Technology Standard (NETS) for Teachers (2002); and what the impact of the selected model is to the preservice teachers’ development of their technology pedagogical content knowledge (TPCK). The three models of technology adoption in teacher preparation programs are then analyzed based on the “Technology Pedagogical
Content Knowledge (TPCK)” diagram (Niess, 2005) that integrates the knowledge of technology, subject matter, and teaching and learning of mathematics (see Figure 1).

*Figure 1 Technology Pedagogical Content Knowledge Diagram*

![Technology Pedagogical Content Knowledge Diagram](image)

*Source; Niess, 2005*

All three areas are viewed as essential components of knowledge that preservice teachers need to develop in order to have the proper and appropriate preparation to integrate technology in mathematics teaching. Lack of any affects the preservice teachers’ success in integrating technology in their teaching with technology. The diagram in Figure 1 describes the knowledge of subject matter that usually focuses on learning of the subject matter only as being integrated with the development of knowledge of technology (denoted by area 4). And the knowledge of subject matter also may have been integrated with the knowledge of teaching
and learning as they begin in the teacher preparation program (denoted by area 6).
Similarly, the knowledge of technology may have been integrated in their
development of knowledge of teaching and learning (denoted by area 5). The main
target of the diagram is the integration of the development of knowledge of subject
matter, knowledge of technology, and knowledge of teaching and learning (denoted
by area 7).

In accordance with a concern for developing such a knowledgebase, ISTE
and the Milken Family Foundation conducted their study in 1999. From the survey
of 146 institutions, all levels of schools, colleges, and departments of education in
the nation, the most important finding was that formal, stand-alone information
technology coursework did not correlate well with scores on items dealing with
technology skills and the ability to integrate information technology into teaching
(Moursund & Bielefeldt, 1999). This finding strongly suggested that the stand-
alone information technology courses are generally not an efficient way to help
new teachers learn to use technology in schools. Based on this finding, the ISTE/
NCATE standards recommended that teacher candidates need to complete “a well-
planned sequence of courses and/or experiences” that help them understand and
apply technology in education (Moursund & Bielefeldt, 1999, pg. 23).

The integrated program model appears more likely to meet the needs of
preservice teachers in developing their TPCK as well as in meeting the NETS-T
standards because of the broader and more intensive opportunity given to learn.
The selection of which model is most appropriate is also highlighted through the
process of how the program help preservice teachers to develop the form of
teachers’ knowledge defined by Shulman (1986). Shulman (1986) described three forms for representing teacher knowledge: propositional knowledge, case knowledge, and strategic knowledge. Shulman stated that teachers are primarily taught in the form of propositions which are similar to lists of facts. The advantages of propositions are that they are economical in form, but they are hard to remember and tend to oversimplify information. Shulman proposed that teachers be taught more along the lines of the second form of knowledge representation, case knowledge. Shulman believed that case knowledge is knowledge of specific and richly described events which teachers can apply to new situations in their classroom. In the setting of preparing preservice teachers to integrate technology in mathematics, observing the faculty and the cooperating teachers model the technology integration in teaching mathematics is the real practice to implement the case knowledge. Finally, Shulman discussed strategic knowledge. While propositions and cases provided the underlying knowledge base for teachers, strategic knowledge emerges into play when teachers encounter a contradiction between two ideas they have learned and they must find a way to apply them to the classroom.

Teacher preparation programs are typically either generic, preparing teachers to teach various levels and various subjects, or subject matter specific programs, focusing on the teaching and learning of a particular subject such as mathematics. The unanswered question is how integrating technology throughout the program affects the preservice teachers’ development of TPCK in a subject-matter specific teacher preparation program. The question for this study is “How do
mathematics preservice teachers develop their TPCK in a subject-specific teacher preparation program that integrates technology throughout the program?” There are two specific questions emerges from the main question; (1) What are the preservice teachers understanding of their TPCK, and (2) How do they practice their TPCK during the student teaching. The study also calls for an additional question: “What features or components of such a program are related to their TPCK development? Important factors or components are identified based on some previous empirical studies on technology integration in teacher preparation programs.

An exploratory case study design was conducted to describe the preservice teachers’ development of their TPCK and search for the most influential components in the program that supported the development. This study followed the program of mathematics preservice teachers throughout a one-year, graduate program in preparation for teacher licensure endorsement. The one year study enabled the researcher to access a thorough description of the courses, projects, faculty, university supervisors, portfolios, cooperating teachers, school sites and real classroom setting. Three cases of preservice teachers with rich description of the participants in the context of the study helped the researcher explore and investigate the answers of the research questions in the study.

**Significance of the Study**

Quality learning requires appropriate knowledge of teaching and learning along with the knowledge of subject matter as well, described in Shulman’s work as pedagogical content knowledge or PCK. With a changing world where the
invention and the development of computer technology and other related devices including video, digital cameras, scanners, graphing calculators, Internet and some scientific probeware, teaching with technology has become an important topic in most educational conferences, meetings, trainings and workshops. With the ISTE standards supported by the NCTM standards that recommend the use of technology, technology concerns have become essential in today’s classrooms. Technology has also become an integral part of teaching mathematics. However, most surveys and report have indicated that the use of technology in the classroom is limited in both the kind of technology being used and the purpose for using the technology (OTA, 1995; Archer, 1998; Market Data Retrieval, 1998; Education Week, 1999; Becker, 2001). This case is similar to the case of teacher preparation programs where the integration of technology in the programs has limited the kind and purpose of use. However, increased research and development of various technology models have led to good progress on how to help the preservice teachers integrate technology in their future teaching.

Analyzing and examining various models, ISTE/NCATE standards recommend that teacher candidates complete “a well-planned sequence of courses and/or experiences” that will help them understand and apply technology in education (Moursund & Bielefeldt, 1999, pg. 23). The need for more directed research in subject-specific teacher preparation programs has become important since the integration of technology in the classrooms is also in specific subject matter and grade levels. This study meets that need by focusing on secondary preservice mathematics teachers in a preservice teacher preparation program that integrate
technology throughout the program. This study explores the development of the preservice teachers’ TPCK upon completion of their preparation program. Identification of the important components in the program that contribute to the development of preservice teachers’ TPCK supports other programs in evaluating and improving the quality of their programs. Identifying roles of specific components in the program in helping the development of preservice teachers’ TPCK also supports the necessary steps in changing and modifying the courses, projects, and specific features needed in teacher preparation programs.

The development of preservice teachers’ TPCK study is still an exploratory study since few studies have described the development of TPCK. Few research studies have addressed TPCK, each with different foci and the subjects in their studies (Pierson, 1999; Keating & Evans, 2001; Woodbridge, 2004; Niess, 2005). This study investigates in-depth cases of preservice mathematics teachers’ development of their TPCK in teaching specific topics in mathematics using technology. Every student is unique in nature. Therefore the exploration of individual cases provides in-depth information and understanding of specific preservice teachers’ construction of their own knowledge through their preparation program facilitating them in constructing their TPCK. Identifying specific components in the program that affect and influence how preservice teachers integrate technology in teaching (such as the courses, projects, portfolio, microteaching, course instructor, university supervisor, cooperating teachers, classroom environments, and also grade level of the students in the school) provides detailed data and information for improving and, if necessary, in
redesigning the components in the program that affect the development of TPCK within the context of mathematics teacher education program.
CHAPTER II
REVIEW OF LITERATURE

Introduction

The term “technology” is more commonly associated with new human inventions of artifacts or tools such as computers, cars, televisions, solar cells, genetically engineered fruit or vegetables (Wright, Yates, & Scarcella, 2003). In an era of information, the computer has become almost synonymous with technology even though, to practitioners and researchers, technology is more accurately thought of in terms of the knowledge and processes that create products (Technology for All American Project, 2000). In its broadest sense, technology is the process by which humans modify nature to meet their needs and wants (Pearson & Young, 2002). Computers technology has refocused how educators think about teaching and learning. According to the Technology Principle in the Principles and Standards for School Mathematics (National Council of Teachers of Mathematics [NCTM], 2000), “Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning." Glenda Lapan, the President of NCTM in 2000, emphasized that technology needs to be used wisely by well-informed teachers to support understanding.

The International Society of Technology in Education's [ISTE] "New Learning Environments" model (see Figure 2) responds to recent research showing that student-centered, constructivist and collaborative learning supports
more effective learning than a traditional top-down, lecture-based, text-driven model.

Figure 2 ISTE’s New Learning Environments

<table>
<thead>
<tr>
<th>Traditional Learning Environments</th>
<th>New Learning Environments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teacher-centered instruction</td>
<td>Student-centered learning</td>
</tr>
<tr>
<td>Single-sense stimulation</td>
<td>Multisensory stimulation</td>
</tr>
<tr>
<td>Single-path progression</td>
<td>Multipath progression</td>
</tr>
<tr>
<td>Single media</td>
<td>Multimedia</td>
</tr>
<tr>
<td>Isolated work</td>
<td>Collaborative work</td>
</tr>
<tr>
<td>Information delivery</td>
<td>Information exchange</td>
</tr>
<tr>
<td>Passive learning</td>
<td>Active/exploratory/inquiry-based learning</td>
</tr>
<tr>
<td>Factual, knowledge-based learning</td>
<td>Critical thinking and informed decision-making</td>
</tr>
<tr>
<td>Reactive response</td>
<td>Proactive/planned action</td>
</tr>
<tr>
<td>Isolated, artificial context</td>
<td>Authentic, real-world context</td>
</tr>
</tbody>
</table>

Source: ISTE, 2000

Accordingly, teachers need to know that a thoughtful use of technology can enrich learning environments and enable students to achieve marketable skills. Educators need to analyze the potential benefits of technology for learning and ultimately take advantage of those benefits appropriately (ISTE, 2000).

An important question concerning technology integration in the classroom is whether technology improves student achievement and learning. Several researchers have considered how the technology has changed and improved student learning and achievement. The Apple Classrooms of Tomorrow (ACOT, 1997) was the first longitudinal study about changes resulting from the routine use of technology by students and teachers in learning and teaching. ACOT investigated a
variety of questions about technology-rich homes and classroom environments over the duration of the project from 1985 through 1997. The project, a collaborative research and development of Apple Computer, Inc., the National Science Foundation, and many universities and research institutions, provided computers to each teacher and student. The project’s purpose was to investigate how the routine use of computers and technology influenced teaching and learning. The study reported that ACOT had a positive impact on student attitudes and on changing teachers’ teaching practices toward more cooperative groups and less teacher lecturing (Sandholtz, Ringstaff, & Dwyer, 1997). Based on their Apple Classroom of Tomorrow (ACOT) project, Sandholtz, Ringstaff, and Dwyer (1997) classified the development of technology implementation into five stages:

1. **Entry** - teachers struggle to cope with and establish order in the transformed classroom.

2. **Adoption** - the beginning of adoption into the traditional classroom

3. **Adaptation** - while traditional teaching methods still predominate, but now supported with technology

4. **Appropriation** - with increasing confidence teachers become confident and pedagogically innovative

5. **Invention** - creativity including active experimentation by teachers and students.

Each stage has its own patterns of change and practices.

In another study, Wenglinsky (1998) investigated the effects of simulation and higher order thinking technologies on a national sample of 6,277 fourth
graders and 7,146 eighth graders mathematics achievement on National Assessment of Educational Progress (NAEP). Wenglinsky found that eighth-grade students who used simulation and higher order thinking software showed gains in math scores of up to 15 weeks above grade level. Eighth-grade students whose teachers received professional development on computers showed gains in math scores of up to 13 weeks above grade level. But the study also reported that both eighth-and fourth-grade students who used drill and practice technologies performed worse on the NAEP than students who did not use drill and practice technology.

Use of technology in mathematics can promote concept development as well as in practice with problem solving. In mathematics teaching, these experiences direct a learning that is more learner-centered and collaborative among the students. Specific technologies for mathematics teaching include various types of calculators, handheld data-collection devices, computers and associated software, and the Internet. Benefits of the use of instructional technology include increased accuracy and speed in data collection and graphing, real-time visualization, interactive modeling of mathematical processes, ability to collect, compute, and analyze large volumes of data, collaboration for data collection and interpretation, and more varied presentations of results. Also, technology can support mathematics classes by focusing on more meaningful and attainable ideas to meet the need of all students. In recognition of this fact, the Technology Principle from the NCTM Principles and Standards for School Mathematics (PSSM, 2000) adds that, “technology should be used widely and
This chapter presents the importance of technology in teaching mathematics as well as in a preservice teacher program, the rationale for selecting a specific integration model in a teacher preparation program, components in a teacher preparation program that potentially affect preservice teachers during student teaching and the roles of those components in helping preservice teachers develop their Technology Pedagogical Content Knowledge (TPCK). These topics lead to a theoretical framework for the research that helps to explore and investigate the problem statement for study: “How do the mathematics preservice teachers develop their TPCK in a subject-specific teacher preparation program that integrates technology throughout the program?”

**Defining Technology Pedagogical Content Knowledge (TPCK)**

The phrase of Technology Pedagogical Content Knowledge (TPCK; referred to as Technological Pedagogical Content Knowledge by some researchers) was originally derived from the idea of Pedagogical Content Knowledge (PCK) by Shulman (1986). TPCK has appeared in research in recent years, but different researchers look at TPCK from different perspectives and levels of study. Pierson (1999) looked at TPCK as a model of technology integration knowledge that practicing teachers need to have in integrating technology in the classroom. Pierson’s integration model consisted of three intersecting circles representing the three types of knowledge. Content knowledge
is what is known about the subject matter being taught. Pedagogical knowledge describes the structure, organization, management, and teaching strategies for how particular subject matter is taught. Technological knowledge includes the basic operational skills of technologies and how technologies can be used in the classroom (Pierson, 1999). The definition of TPCK was described in a clearer context of preservice teachers in the study of Keating and Evans (2001). They found that although preservice teachers felt comfortable with technology in their daily lives and school works, they expressed worries about using technology in their future classrooms; that is, they lacked “Technological Pedagogical Content Knowledge” (p. 1). The idea is similar to that which Pierson, Keating and Evans built from Shulman’s (1986) idea of PCK that goes beyond knowledge of subject matter content to knowledge of how to represent subject matter to develop understanding in students’ thinking. Thus, Keating and Evans indicated that “technological pedagogical content knowledge extends beyond proficiency with technology for personal use to an understanding of how technology can be integrated with subject matter and the technology itself…. The teacher understands the…inevitable challenges that accompany any new technology.” (2001, p. 2). In more specific detail, Niess (2005) elaborated on TPCK extending Grossman’s (1989, 1990) four central components of PCK. Transforming these components in terms of technology in teaching provided direction to an outline of the teacher preparation program: (1) an overarching conception of what it means to teach a particular subject integrating technology in the learning; (2) knowledge of instructional strategies and representation for teaching particular topics with
technology; (3) knowledge of students’ understanding, thinking, and learning with technology in a particular subject; (4) knowledge of curriculum and curriculum materials that integrate technology with learning in the subject area (Niess, 2005).

However, in practical and empirical terms for how mathematics preservice teachers develop their TPCK has not been explored and studied. Most of the studies on integrating technology in teacher preparation programs focus on the effect of specific treatments or features of the program on preservice teachers. Numerous studies describe the effect of field experiences that support the integration of technology by preservice teachers (Strudler & Grove, 2002), sequence of courses with practice-oriented technology components to change preservice teachers’ perceptions of the role of the teacher in teaching with technology (Stuhlman, 1999), and the effect of four sequence courses to preservice teacher’s confidence level and their use of technology in the classroom (Pope, Hare, & Howard, 2002).

One example of a specific topic in mathematics for how TPCK is blended into an integration of the knowledge of subject matter, teaching and learning and technology in the preservice teachers’ program is an activity that explores the Pythagorean Theorem using *The Geometer’s Sketchpad* (Garofalo, Drier, Harper, Timmerman, & Shockey, 2000). The emphasis of the activity is more on the principles of teaching the mathematics than on the mathematics itself. Preservice teachers discuss how this topic is traditionally taught to students, as a rote memorization of $a^2 + b^2 = c^2$ without a conceptual understanding that $a^2$, $b^2$ and $c^2$ represent areas of squares with sides length $a$, $b$, and $c$. The class then discusses
how technology can be used to enhance the students' understanding of the theorem, and guides them through a model lesson of how the Pythagorean Theorem could be taught using Sketchpad. Preservice teachers are first asked to use the Sketchpad to construct a right triangle, measure each side, and numerically confirm the $a^2 + b^2 = c^2$ relationship. They then learn how to use Sketchpad features to script a construction of a square. Next the preservice teachers play back their scripts to place a square on each of the sides of the right triangle and add measurements to create a construction similar to the one in Figure 3. The dynamic Sketchpad environment allows them to drag the triangle's vertices or sides to manipulate the construction, keeping the characteristics of the geometric figures intact. As the construction changes, the sum of the area of the squares on the legs of the right triangle always remain equal to the area of the square on the hypotenuse of the right triangle. Preservice teachers then discuss connections between the different representations of the Pythagorean Theorem, advantages of each representation in teaching this topic, and benefits of using the Sketchpad to create and manipulate the constructions. The misconceptions that might occur in teaching using this technology also are discussed so that they can plan a better way of presenting the lesson to avoid or attend to those misconceptions.

Researchers have identified specific ideas and ways of helping preservice teachers to gain certain knowledge of TPCK that in turn helps them apply the ideas as they understand them. However, how preservice teachers construct or develop their TPCK when they are involved in a technology course or teacher
preparation program that integrates technology is a more essential research question to be considered at this time.

Figure 3 Sketchpad’s File of the Pythagorean Theorem (Garofalo et al., 2000)

Technology Integration Models in Teacher Preparation Programs

Technology has been incorporated into teacher preparation programs in numerous ways. One way to categorize these approaches is according to the primary user or controllers of the technology in the teacher preparation program: the teacher educator, the teacher, and the preservice teachers (Lederman & Niess, 2000). Another way to categorize the adoption models is with the setting of the courses. Three models are currently considered by researchers as to the adoption in technology course(s) in teacher preparation programs (Cassady & Pavlehcko, 2000; Mehlinger & Powers, 2002; Wetzel, 1993). The primary model used in
teacher preparation programs is, and has been, the *single course* model. A second model combines several courses into a sequence or a summer institute or workshops in teacher preparation programs. A third model integrates the technology throughout all the work in the entire teacher preparation program.

**The Single Course Model**

Typically, teacher preparation programs offer one course in which preservice teachers are to develop their basic technology skills to serve them as the foundation for their ability to integrate technology into the K-12 curriculum (Hargrave & Hsu, 2000). These courses, offered early in the teacher preparation program with the courses, range from one to six credit hours each (ISTE, 1999). The single course is chosen as the model because many of the new students who enrolled in the teacher preparation programs have various skills and knowledge of technology; in some cases they need to have develop skills in using various technologies and in other cases they already have those skills. But, they also need a technology course for their teacher licensure that focuses on using various technologies in teaching, such as word processors, email, basic web development, and Internet searches, are the most common technology applications taught in this single course (Hargrave & Hsu, 2000).

Several researchers who studied this *single course* model aimed to implement the integration of knowledge of subject matter, knowledge of technology, and knowledge of teaching and learning but the intensity was limited and short (Willis & de Montes, 2001; Gunter, 2001; Bauer, 1998). A limited target
of TPCK integration in these models indicated that their objectives of the study were, for example: to “enable the students to ‘do’ technology and ‘be’ desktop publishers and multimedia developers and database managers by using technology tools in a safe learning environment” (Willis & de Montes, 2001); introduce and practice using software programs immediately followed by practical application of software in an educational setting (Gunter, 2001); become acquainted with “Oregon Trail software” to prepare preservice teachers for future teaching (Bauer, 1998).

The low level of attaining TPCK on this single course model was described in two parts: the length of time spent on the course; and, the kind of technology used in the course. One course usually last only 10 or 16 weeks. The technologies learned in this course were also limited to basic application of word processors, email, basic web development, and Internet searches. In terms of helping preservice teachers to form the kind of knowledge, this single course model only provided the preservice teachers with a propositional knowledge because in this model they were not exposed to cases about the use of the technology in education and confronted with real teaching situations where technology was involved. Evaluating this model with respect to the National Educational Technology Standards for Teachers (NETS-T, 2003), the single course model typically included the basics operations and concept of the technology. Some studies (such as, Willis and de Montes (2001) and Gunter (2001)) required that the preservice teachers design a lesson where technology was included in the plan, (referred to as “a unit of practice”). However, the preservice teachers were not required to implement the plan they designed in the real classroom. Those two activities indicated that NETS-T Standards 1 and 2
were considered (1: Basic Operations and Concepts; 2: Planning and designing learning environments and experiences). Besides these two requirements, preservice teachers were required to submit the products of the class in the form of technology integration, such as web portfolio sites, power point presentation, Hyperstudio stack, and QuickTime movies (Bauer, 1998; Willis & de Montes, 2001). The issues of the ethical, principal, and legal and human issues standard were demonstrated in their web portfolio as they were required to have their own work on the portfolio web sites. These outcomes demonstrated what this single course considered - the NETS-T Standards 5 and 6 (5: Productivity and professional practice; 6: Social, ethical, legal and human issues) (Willis & de Montes, 2001).

The Component of Courses Model

The components of courses model included opportunities for integrating TPCK focused primarily on student teachers, without collaboration with cooperating teachers, and were more likely to perform better in terms of emphasizing TPCK (Pope, Hare, & Howard, 2002; Cassady & Pavlechko, 2000; Stuhlman, 1998). Three studies that integrated the technology in selected core courses were mostly on the method courses such as four different method courses (science, math, language arts, and social studies in Pope, Hare, & Howard’s study), three sequential core courses (Cassady & Pavlechko’s study), and two courses in the program (Teaching, Schooling and Society; Special Populations and Cultural Diversity and Methods for Using Computers in Classrooms in
Stuhlman’s study). Methods courses had the possibility for enriching the knowledge of teaching and learning. The content may have been covered at the same time even though the amount perhaps was limited. With technology integration in the methods courses, the intensity of attaining TPCK in the programs was higher than with the single course model. The component of courses model explored more examples of appropriate use of different technologies in specific subject matter.

The components of courses model helped preservice teachers to build all three forms of teachers’ knowledge, propositional, case, and strategic (Shulman, 1986). The teachers’ case knowledge has been clearly indicated in several studies (Strudler & Grove, 2002; Wetzel and Zambo, 1996; Johnson-Gentile, Lonberger, Parana, & West, 2000). In these studies, pairs of cooperating teachers and preservice teachers worked together for integrating technology. All of the studies worked on developing the strategic knowledge where they had to teach with technology in their student teaching but some had more opportunities than others because the different levels of support from faculty supervisors, cooperating teachers, and school administration. These preservice teachers were more likely to teach with technology and formed a clearer strategic knowledge using this model as the students had opportunities to practice teaching with technology in their field experiences and felt supported by their cooperating teachers (Strudler & Grove, 2002). The components of courses model was designed to accommodate the needs of having enough basic technology and operations along with an integration of technology with the subject matter and teaching and learning.
Most of the studies in the *components of courses* model provide preservice teachers with the opportunity to not only design lessons but also to implement the lessons in real classroom with the real students. One example was the study by Pope, Hare, and Howard (2002). The preservice students in the study were required to teach preplanned lessons incorporating the technology and methods they had learned in the courses. Teaching in the field experience gave the preservice teachers an opportunity to provide a context needed to enable them to make connections between the theory and practice of teaching, learning and curriculum in an actual classroom. These notions indicated that the *components of courses* model met the NETS-T standards 1, 2, and 3 (1: Technology operations and concepts; 2: Planning and designing learning environments and experiences; and, 3: Teaching, learning and the curriculum). Similarly, in terms of the preservice teachers’ uses of technology to enhance their productivity and professional practice as well as issues related to social, ethical, legal, and human issues, this model provided some evidence, such as in the study by Bayerbach, Walsh, and Vannata (2001). Their study was about an issue of teaching preservice teachers to support social justice with the focus of using technology to expand preservice teachers’ understanding of diversity, equity awareness, and cultural responsiveness using a variety of interactive communication technologies, such as the use of two-way interactive videoconferencing between and among diverse contexts. Preservice teachers were required to conduct research using the Internet in preparing their lessons. These two activities showed their effort to meet NETS-T Standards 5 and 6 (5: Productivity and professional practice; 6: Social, ethical, legal and human issues). No evidence
was found in the research as to how this model supported preservice teachers in evaluating and assessing their teaching with technology.

The Integration of Technology Model

The Integration of Technology model focused on integration of teaching with technology throughout the preservice teacher preparation program. Teacher preparation programs that adopted the Integration of Technology model are those who have been involved in the process of integrating technology in their program for a number of years. One example was documented in a study at Arizona State University West (Wetzel, 1993, Wetzel & Zambo, 1996; Zambo, Beckett, Wetzel, & Marquez-Chisholm, 2002; Wetzel & Williams, 2003). The Integration of Technology model was best summarized in the article titled “It Takes a Village To Create Fearless Users of Technology” (Wetzel, Williams, Padgett, & Odom, 2002). The idea was that several years are needed for infusing technology instruction throughout the teacher education program in order to prepare new teachers to integrate technology into their K-12 classroom teaching.

The integration of technology model is a similar design with the component of courses model in terms of aiming at the TPCK and forming the teachers’ knowledge; however, the integrated model has more time and opportunities to spend on different models and exemplary teaching. The Niess (2005) and Zambo, Beckett, Wetzel, and Marquez-Chisholm (2002) studies demonstrated compelling achievement in terms of TPCK. The qualitative data in Niess’ study detailed how preservice teachers developed their TPCK with assistance from university faculty,
supervising teachers and cooperating teachers. Besides putting the emphasis of the study on teachers’ knowledge, Niess’ study also identified three important elements of teacher’s decision making stages: preactive, interactive, and post-active. Case knowledge is formed when the preservice teachers move to the school setting to observe and complete their part-time internships. Through three stages of the program, the preservice teachers were more likely to acquire and form strategic knowledge as they prepared, practiced and reflected on their teaching after student teaching. Therefore, Niess’ study suggested that identifying appropriate strategies and the importance of planning were essential parts in a successful integration of technology.

The Zambo, Beckett, Wetzel, and Marquez-Chisholm (2002) study revealed a different approach as they built the case and strategic knowledge of the teachers. By pairing the preservice and cooperating teachers, the study gave an opportunity for preservice teachers and mentor teachers to become acquainted and to develop a collaborative working relationship prior to the school year while creating the technology-integrated unit of practice (UOP) during the workshops. Preservice teachers formed their case knowledge while working with the cooperating teachers. The requirement to teach at least one UOP during the following semester after the workshop was an indication that the preservice teachers developed a strategic knowledge. However, the study did not highlight the reflective part after the preservice teachers taught one of the UOPs in their student teaching field experience.
The integration of technology model has more opportunities for distributing technology integration into the courses in the program. Mirroring this model in the NETS-T standard was clearly described in the Niess’ study (2005). Niess’ study gave the descriptions of each course taken by preservice teachers including the first quarter of the program, a specific technology course that used problem-based activities to guide the preservice teachers in learning about the technology, learning and teaching with technology, and learning and teaching the specific mathematics and science in technology setting. The technologies included Internet applications, spreadsheet, word processor, graphing calculator, and other real time data collection devices. The next quarter of the program required the preservice teachers to develop and teach a mathematics or science lesson to their peers, and then reflect on the lessons. The development of lesson plans continued to a sequence of lessons that included student hands-on experiences with technology in the form of a Technology Instruction Notebook. During the fulltime student teaching, the preservice teachers were required to implement their preplanned lessons in actual classroom situations. At the end of the program, a follow-up course focused on the impact of the instruction on student understanding using some guidelines for the discussion. The student teachers’ final report of the success and obstacles on implementing the lessons was then revised and reflected in a form of a final Technology Instruction Notebook. The whole process showed the rigid and detailed process of how the program met all the NETS-T Standards.
Figure 4 provides a summary of all the models of technology integration in teacher preparation programs alongside with the three frameworks that outline TPCK identification (Niess, 2005), forms of teacher knowledge (Shulman, 1986), and NETS-T (ISTE, 2001) of selecting the program model.

The first column on the Figure 4, shows that some of the single course models tended to aim their studies on the integration of knowledge of subject matter, knowledge of technology, and knowledge of teaching and learning but the intensity was limited (Willis & de Montes, 2001; Gunter, 2001; Bauer, 1998). One study by Willis and de Montes showed how they integrated those three knowledge bases by using the performance-based projects that integrated technology tools in teaching. A limited target of integration of TPCK in these models indicated in at least one of the objectives of the study, to “enables the students to ‘do’ technology and ‘be’ desktop publishers and multimedia developers and database managers by using technology tools in a safe learning environment” (page 77). Similarly, Gunter also described the limitation of the integration of TPCK on the objectives of her study (introducing and practicing of software programs immediately followed by

<table>
<thead>
<tr>
<th>Model of Integration</th>
<th>TPCK</th>
<th>Form Teachers’ Knowledge</th>
<th>NETS-T</th>
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</thead>
<tbody>
<tr>
<td>Single Course</td>
<td>Low</td>
<td>Propositional Case</td>
<td>1,2,5,6</td>
</tr>
<tr>
<td>Component of Courses</td>
<td>Medium</td>
<td>Propositional Case</td>
<td>1,2,3,5,6</td>
</tr>
<tr>
<td>Integration of Technology</td>
<td>High</td>
<td>Propositional Case Strategic</td>
<td>1,2,3,4,5,6</td>
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</table>
practical application of software in an educational setting). She implemented the course with the 50% lecture format in a presentation classroom and 50% hands-on in a computer lab. Bauer’s study identified the limitation of the integration of TPCK that was clearly indicated in the technology he used in the class, using the “Oregon Trail software.”

The limitations of attaining TPCK on the single course model were indicated in two aspects: the length of time spent in the course and the kind of technology used. These limitations were most likely caused by the timing available in a single course. Another important issue was that the single course model lacked attaining the TPCK through their methods of assessing the objectives of the courses. The objective assessments were mainly completed by survey, questionnaires (such as attitudes toward technology, self-efficacy using technology, computer technology experience and rating scale, computer attitude scale (CAS)), and only one interview (Gunter, 2001).

As indicated in Figure 4, the integration of technology model as the model has the most potential for affecting preservice teachers’ construction of their TPCK. In support of this issue, ISTE and the Milken Family Foundation studied how teacher preparation programs focused on helping their preservice teachers adopted those different models. From a survey of 146 institutions, the most important finding was that formal, stand-alone information technology coursework did not correlate well with scores on items dealing with technology skills and ability to integrate information technology into teaching (Moursund & Bielefeldt, 1999). This finding strongly suggested that stand-alone information
technology courses were generally not an efficient way for helping new teachers to use technology in teaching. From this finding, the ISTE/NCATE standards recommended that teacher candidates “complete a well-planned sequence of courses and/or experiences” to help them understand and apply technology in education (Moursund & Bielefeldt, 1999, pg. 23).

The model for this research study was chosen based on several considerations as to how technology could have a larger impact on the preservice in integrating technology in their teaching. Three considerations supported the selection of integration of technology model:

- The understanding of the integration of subject matter, teaching and learning (or pedagogy) and technology, or TPCK (Niess, 2005)
- Forms of teacher’s knowledge (Shulman, 1986)

Based on the enhanced Grossman considerations (Niess, 2005), the integration of technology model has more potential for influencing preservice teachers’ practice and the development of their TPCK during student teaching.

**Components of the Integration of Technology Model**

Important components in the integration of technology model for consideration affects on how preservice teachers develop their TPCK. Those components are identified based on previous empirical studies that have been completed in teacher preparation programs. Those components are classified into
two main sources: on campus-based and off campus-based. The on campus-based components consist of course work, microteaching, portfolio or work sample, course instructor, and university supervisor. The off campus-based components consist of part time student teaching and cooperating teachers. These components are practical and operational features in the programs that involve and interact with the preservice teachers. They all are inter-related. The course instructor and the course are related, but the categorization is made in order to see the specific support from the research as to how each of those specific components affect the preservice teachers’ TPCK as they participate in the preparation program.

The first component in the on campus-based teacher preparation program is the course. Courses are a main source for preservice knowledge to acquire and learn what the teacher preparation programs offer and provide. As part of the growing concern on developing an integrated course to enrich the technology environment and model the use of technology, teacher preparation programs have incorporated various types of courses. Willis and de Montes (2001) developed a Multimedia Content Development Company (MCDC) model in a teacher preparation program. Gunter (2001) designed a course that consisted of 50% lecture format and 50% hands-on in a computer lab for one semester period, three hours a week. Ertmer, Lewandowski, Osika, Selo, and Wignell (2003) also designed a model of exemplary technology-using teachers in a CD-ROM emphasis, called Vision Quest for 12-week periods. In a different setting, Bauer (1998) used the Oregon Trail educational software created by Minnesota Educational Computing Consortium (MECC) as an anchor in a one semester technology course for
preservice teachers. Those various types of courses were designed with the same objectives of how preservice teachers can learn the appropriate knowledge that they can use in their student teaching and future career. In general the effect of only one course is limited to a specific skill of technology use, attitudes toward computer technology, level of self-efficacy using computers, anxiety and confidence about computer technology, and various stages of concern in adopting technology. However, courses provide important sources of knowledge that preservice teachers’ need, knowledge of technology, content, and teaching and learning.

Microteaching is an organized practice teaching. The goal is to give preservice teachers confidence, support, and feedback by letting them practice with their classmates a short slice of what they plan to do with their students. Ideally, microteaching sessions take place before preservice teachers use the lesson in real classroom and are videotaped for personal review with an experienced teaching supervisor or instructor. Microteaching is a quick and efficient way to help preservice teachers’ practice teaching with technology. The quality of the microteaching performance usually is thought to be an excellent predictor of quality of later classroom performance (Copeland, 1975). Preservice teachers generally view microteaching as an interesting, enjoyable, and valuable experience (McCleod, 1987). Research studying the importance of microteaching in using technology in teaching usually combines with larger components in teacher preparation program, such as specific courses on technology in the classroom or student teaching experiences. Eugene (2003) studied microteaching as part of a study that focused on the reflection of preservice teachers during their student
teaching. The study investigated the development of reflective practice in assisting preservice teachers in integrating their learning experiences and in the analysis of their actions in their endeavors to become more effective learners and teachers of mathematics. In Eugene’s study, students used their journals to reflect on their experiences with reference to various aspects related to the teaching and learning of mathematics. The study relates their insights and experiences, and highlights the importance of reflection on students' development beyond levels of technical rationality with respect to teaching mathematics.

The instructor and the course are usually integral parts of a teacher preparation program. However, the instructor or faculty that model technology in their teaching has an important role in shaping the image of preservice teachers about the importance of technology in teaching. At Arizona State University West, the College of Education (COE) faculty sought reason(s) their graduates did not feel prepared to teach with technology. One of the reasons identified was that the students did not see faculty model technology use in the preservice courses. Therefore, the main objective of their research project was focused on ways to change the faculty at their institution so that they all modeled the use of technology in teaching (Wetzel & Zambo, 1996).

The off campus-based components are mainly composed of student teaching experiences and interactions with cooperating teachers. They are interrelated and operate as a single package model. Teaching experience or student teaching is one of the most important elements in the initial teacher education. These opportunities provide student teachers avenues for teaching in real classroom settings before
assuming sole responsibility for instruction (Goodman, 1986; Metcalf, Hammer & Kahlich, 1996). These components also provide a learning opportunity through which student teachers can check whether theories learned in their program or coursework fit into real teaching situations; hence, they are provided with an opportunity to practice and develop their own teaching and learning theories accordingly with the support of university supervisors and mentors or cooperating teachers (Goodman, 1986; Okland, Fernandez & Kueter, 1995). Through student teaching that is properly planned, supervised and supported by university supervisors and teachers, student teachers can also take ownership of and responsibilities for their own professional development (Chin & Russell, 1996; Metcalf, Hammer & Kahlich, 1996). The student teaching activity also can be used to capture the part of student teachers’ professional training that involves professional growth through experience and practice.

However, while acknowledging that the field experiences previously described is important in initial teacher education, field experiences do not automatically result in positive experiences (Berliner, 1985; Metcalf, Hammer & Kahlich, 1996). In relation to supporting preservice teachers in integrating technology during their student teaching, several studies have taken place in different settings and with different methods. Strudler and Grove (2002) studied and investigated the effect of a “two-pronged” approach in restructuring teacher candidates’ field experiences to support the integration of technology in preservice teachers - Cluster School Model and Paradise Professional Development School Model. The main finding from the study was that student teachers gain sufficient
opportunities to teach with technology in their field experiences. Another finding is that student teachers that felt supported by their cooperating teachers are more likely to teach with technology.

In a different situation, Wetzel and Zambo (1996) also investigated the effect of a project designed to improve the preparation of grade 3-8 mentor and student teachers to teach mathematics and science through the integration of multimedia technology and pedagogy. The project consisted of a summer training institute, an intensive two-week professional development program and implementation of project strategies during the following fall. The study found that the student teachers increased their rating in their understanding of technology and ability to use it in instruction. The student teachers also felt more prepared and confident in their ability to solve software and hardware problems, select software for instructional purposes, and teach children to use productivity and multimedia tools.

Cooperating teachers serve as the student teachers’ mentors and evaluators during the student teaching experience. They observe students, provide feedback and suggestions for improvement, aid with curriculum development, and socialize students to the role of teacher. The student experience in teacher preparation programs is considered as a professional leadership responsibility that requires in-depth analysis of teaching and learning, designing a learning environment to facilitate inquiry, use of technology to make connections and solve problems, use of traditional and alternative assessments that are equitable, use of university, school, and community resources as well as communications through the language
of mathematics. In supporting student teachers to teach using technology, the role of cooperating teachers are considered as essential for the student teachers’ development. Because their role is critical, they can benefit from preparation for their roles. One of the research findings indicated that preservice teachers have inadequate opportunities to practice the integration of technology into educational practice (Strudler, 1999; NCATE, 1998). When the support from the cooperating teacher is high, student teachers are more likely to use the technology in their student teaching (Strudler & Grove, 2002).

These six components have shown their significant roles in helping preservice teachers to be better prepare in teaching with technology. As part of the structure of a teacher preparation program, these components are interconnected. These six components’ roles can be categorized into three parts: designing the technology lessons, practicing what they have planned, and reflecting upon their practice teaching with technology. In designing the technology lessons, several steps and stages are built using a scaffolding approach based on the level and readiness of the preservice teachers in the program. Designing is usually being stressed out during the coursework. Preservice teachers need necessary knowledge and understanding to design technology lessons. That knowledge involves not only the mathematics concepts but also the appropriate instructional strategies and technology selected for certain level of students understanding. Some preparation programs require preservice teachers to demonstrate or exhibit development of their skills in designing the technology lessons in a work sample or e-portfolio. Through instructors who model the effective use of technology, the preservice teachers are
guided in practicing what they have designed. Peer teaching is a place to facilitate that need. The reflection part can be accomplished during the course work, peer teaching, and student teaching. The real challenge for preservice teachers is when they become student teachers in actual classroom settings, preparing to teach with technology. By nature, the culture of school is different from the experiences in the teacher preparation program, including the technology facilities, technology support, and the cooperating teacher. Cooperating teachers in general are supportive of the preservice teachers. The role of the cooperating teacher is as the primary person in charge of guiding the preservice teacher in gaining control of the students in the classroom. Cooperating teachers who have more technology background and experiences of using technology have the ability to assist more in the integration of technology in the classroom.
CHAPTER III

METHODOLOGY

Introduction

The main purpose of this study was to investigate secondary mathematics preservice teachers’ development of their technology pedagogical content knowledge (TPCK) in a subject-specific teacher preparation program that integrates technology throughout the program. The study leads to the question of how an integrated model supports preservice teachers in developing their TPCK by specifically considering the features or components of the program that are related to their TPCK development. Gathering extensive information on the preparation program supported the researcher in designing a model to describe the relationship among the components and how they supported the development of preservice teachers’ TPCK during their student teaching experience.

In this chapter, the description of the method and design are elaborated upon within the context of the study. The study used a case study design with an exploratory approach to investigate the preservice teachers’ development of their TPCK during their full time student teaching experience. The context of the teacher preparation program where the preservice teachers’ progressed in the process of becoming teachers is described. This chapter also describes the selection process of the participants including the rationale for the step-by-step purposeful sampling that was used. The data sources, data collection, and data analysis are also included in this chapter.
Design of the Study

This study used an exploratory multiple-case study design where considerable uncertainty existed about the roles of specific influential components in the development of preservice teachers’ TPCK through the courses, microteaching, student teaching, and interactions with instructors, university supervisors, and cooperating teachers in the program. In the context of TPCK, the theoretical background of this model is in its infancy in describing its development through teacher education program, particularly in mathematics teacher education. Therefore, specific guidelines for how specific features or components impact the development of preservice teachers’ TPCK are still in progress. For elaborating the case, the present study involved an in-depth, thorough examination of preservice teachers through a systematic observation of their work throughout their student teaching, collecting data, analyzing information, and reporting the results (Tellis, 1997). This exploratory study developed three preservice teacher cases, purposefully chosen for the expectation of gaining in-depth and sufficient information about preservice teachers’ development of TPCK and their practice in teaching mathematics with technology. Purposeful sampling was chosen to maximize the opportunity to learn in the limited time of the study (Stake, 1995). Hence, the cases were selected to be uncomplicated, using willing subjects from mathematics preservice teachers involved in a teacher preparation program that integrated technology throughout the program. The model focused on obtaining a rich, broad, and in-depth description of what and how the components of the
teacher preparation program influenced the preservice teachers’ development of TPCK.

The researcher carefully documented the teacher preparation program from beginning until the end. Consistent observation of all courses in the program provided an understanding of the program for describing the context, treatments, and features that supported the development and implementation of preservice teachers’ TPCK. This method also allowed the researcher to observe the preservice teachers as they designed, planned, and practiced their lesson plans in preparation for the student teaching. Observations during student teaching and interviews before and after their teaching provided an opportunity for an in-depth understanding of the impact of the teaching environment where the preservice teachers had full instructional responsibility for specific classes. To provide more supporting evidence, all the course documents, class artifacts, and preservice teachers’ work-samples were collected and analyzed.

**Teacher Preparation Program Model**

The teacher preparation program in the study was a one-year, graduate level content-specific teacher preparation program for mathematics and science teaching. Even though the program had both majors in both science and mathematics, the focus of this study was only on the mathematics majors. The program integrated learning about and teaching with electronic technologies as an integral component in teaching and learning science and mathematics, grades 3-12. The emphasis of the program was on the development of a teacher’s ability to transform what he or she
knows into teaching strategies that make that knowledge accessible to learners. The program began with technology summer coursework, providing the foundation for the program and preparation for the school-based practicum experiences integrated throughout the various terms of the four-term program. All courses in the program implemented the importance of integrating technology in a variety of ways such as the faculty modeling teaching with technology, requiring technology in the assignments, and providing opportunities for practice teaching with technology.

The program integrated school-based practice with the on-campus coursework during the program. The fulltime student teaching was situated in the final term of the program, Spring term. Student teachers were required to teach a sequence of technology lessons designed and planned during the terms prior to student teaching, Summer, Fall and Winter. The preparations of those lessons were integrated into a sequence of technology and pedagogy courses taught during Fall and Winter terms. The courses were designed in such a way that the preservice teachers were able to design technology resource cards, integrate various technologies into resource cards, identify online resources for teaching, expand the resources into short lesson plans, design an extensive, detailed lesson plan, review and evaluate lesson plans of others, practice teaching of the lesson plan in a microteaching environment and evaluate others’ teaching. During the student teaching experience, student teachers were expected to provide evidence of their thinking by writing reflections of lessons taught, videotaped lessons, analyze their teaching, incorporate quizzes and assessment, plan for future teaching, and complete their work sample project as part of the program and licensure
requirements. Appendix A contains a display that provides a term-by-term description of the teacher preparation program in this study.

**Technology Sequence Courses in the Teacher Preparation Program**

Since the research study is focused on the components of the program that affected the preservice teachers’ development of TPCK, the program, itself, provided one of the major sources of data. The program (outlined in Appendix A) was designed so that in each term, the preservice teachers were required to take a course that considered teaching with technology. Throughout the four terms with the fulltime student teaching in the final term, the program offered a sequence of technology courses that prepared the student teachers for teaching with technology.

The first course (SED 412) during Summer term provided a foundation for mathematics and science preservice teachers in teaching with technology. This course covered most major technologies found in the classroom, such as calculators, spreadsheets, presentation software, webpage design, multimedia graphics and motion presentations, and several handheld probeware devices. The general objective of the course was to introduce and model teaching mathematics and science concepts with technology. Preservice teachers were given opportunities to explore, design, and present their various technology skills in a short electronic portfolio (e-portfolio) presentation. Besides displaying their technology expertise, the preservice teachers created a short lesson plan that integrated technology and reflected their work with the various technologies and in designing the technology lesson.
Additional courses during the Summer session supported the work in the technology course. The Math Materials and Labs course (SED 414) focused the mathematics preservice teachers on specific pedagogies and materials for teaching mathematics. Additionally the students completed an adolescent psychology course to focus their attention on the psychology of the students at the level they were preparing to teach.

Fall and Winter terms focused the student teachers on methods for teaching mathematics (SED 552 and 554) and classroom management and diversity (SED 511 and 515). These courses provided basic knowledge and skills about classroom management, instructional strategies, planning lessons, assessment and evaluation, knowledge about learning theories, and current issues in American education.

Fall term was divided into three parts: a one-month fulltime practicum in a school-based setting, a one-month period of campus coursework and a five-week period that included morning student teaching practicum in their practicum school site and afternoon campus-based university coursework. During the one-month period of campus-based university coursework, the students were focused on methods and pedagogies for teaching. Their methods course (SED 554) guided them in the development of a work sample that was to be taught during the five-week student teaching practicum. The technology emphasis was integrated with the mathematics pedagogy course (SED 574) (separating the mathematics preservice teachers from the science preservice teachers) focused on the details of developing lesson plans that integrated technology. In this course they practiced teaching their lesson plans in a microteaching setting. The technologies emphasized
in this class included calculators, spreadsheets, and Geometers’ Sketchpad. The preservice teachers worked in groups of two to develop their lessons on assigned topics then taught the lessons in a microteaching setting. In addition, the group also designed a short lesson as a warm-up for the lesson. At the end of each microteaching session, one of the groups was assigned to lead a discussion debrief on the successes, barriers, misconceptions, and any other related teaching and teaching with technology issues.

During Winter term, preservice teachers took four courses and focused on the preparation for their student teaching during Spring term. The main goal of the coursework was to help the preservice teachers to begin planning a second work sample and a sequence of the technology lessons.

The Advanced Topics in Mathematics (SED 589) course was focused on pedagogy and integrating technology. This course was specifically designed to help the mathematics preservice teachers to develop, practice, evaluate, and analyze a sequence of technology lessons that they planed to teach in their student teaching experience during Spring term. The design of the course was similar to the technology work Fall term (SED 574) giving the preservice teachers the sense of a continuation of the technology emphasis. This course adopted Shulman’s idea (1987) of three different types of teachers’ knowledge: proposition, case, and strategic knowledge. At the proposition stage, the preservice teachers only had a chance to listen and observe what the teaching with technology in mathematics was. On the case stage, the preservice teachers were given the opportunity to watch and discuss actual cases where technology was involved in the classroom. Several
videos were shown to the preservice teachers to compare different ways of teaching with and without technology involved in mathematics classroom. As a follow-up of this stage, the preservice teachers developed their own technology lesson based on the information given by the program as to the level and topic they would be teaching during Spring term student teaching. The development of the lesson began by collecting a variety of ideas and describing them in resource card format. The technology lesson was extended to a sequence of technology lessons consisting of at least three lessons. The technologies chosen for the project could vary depending on availability at their school sites.

By the middle of the term, preservice teachers were assigned to practice teaching their lesson in another microteaching situation. While one of the preservice teachers was teaching, one of them did the observation, one wrote a feedback that was given the next session, and one preservice teacher conducted the debrief, leading the discussion about successes and barriers from the lesson just taught. At the end of the course, the students had two final projects: the sequence of three technology lessons (the beginning of their technology work sample) and an electronic portfolio that contained updated information about their accomplishment in the program. Thus by the end of this term, preservice teachers were expected to have initiated their plans for integrating technology in teaching mathematics with technology. The other courses in the program focused on the development of additional plans for student teaching during Spring term.
Participants

The researcher identified three specific cases from a cohort of nine preservice teachers enrolled in the mathematics preservice teacher program during the 2004-2005 school-year. Three participants were selected to represent the diversity of the group. The three participants had general characteristics of the population in addition to their uniqueness in personalities, characters, and backgrounds. Another consideration for the selection was for the efficiency of the study. Observing and interviewing nine preservice teachers in the 11-week timeframe of the student teaching experience in order to gather in-depth and detailed data was not possible for a single observer.

Selection of the participants began through an in-depth consideration of their educational backgrounds, technology expertise, gender, and grade levels for teaching. Following the students through the program and observing their progress in the courses provided more information about the context of their development, learning styles, and the quality of their participation and engagement in the program. Different university supervisors were identified to find out whether there was an impact of various university supervisors on preservice teachers, their performance in the program, and their development of TPCK. Participants were selected from both university supervisors available at the time of study. The varieties of teaching styles were identified from observation of students in their part time teaching during Fall term. Five teachers were observed during the part time student teaching. These five were selected from the nine after eliminating students from subject matter backgrounds other than mathematics (e.g., engineering) and
another student work experience in different fields before entering the program and students with English as a second language. The goal was to focus on traditional mathematics education students. One of the nine also had a cooperating teacher who refused to have the study involve classroom observations. The five preservice students who were identified included one African American and four Caucasian, two males and three females, and students with an age range of 22-29 years. All five had majored in mathematics with various teaching experiences ranging from two to three months of informal teaching experiences and one with three months of formal teaching.

Research has indicated that preservice teachers are focused mainly on controlling the class rather than on specific tasks of teaching (Fuller, 1969; Hawley & Rosenholtz, 1985) and tend to be less aware of instructional sequences and the meaning of classroom events than experienced teachers (Carter et al., 1988). Thus, the primary purpose of the Fall term observation was to identify preservice teachers who had fewer concerns with classroom management. This consideration allowed the researcher to focus on the preservice teachers’ teaching with technology rather than struggling with classroom management issues. Thus, when these preservice teachers were student teaching, they were better able to focus on teaching the mathematics lessons in the classroom.

The Fall term observations indicated that all five were similar in ability to manage the classroom. Thus, the next step was to consider their school placements. Since secondary preservice teachers were the subjects of the study, the school sites chosen for the study were either middle or high schools. Selections of the
participants inevitably lead to selection of particular school sites and cooperating teachers. Cooperating teachers were contacted after student teachers indicated their willingness to participate in the study. Short visits and introduction to the school and classroom were conducted after the cooperating teachers approved their involvement in the study. The preservice teachers facilitated most of the following communications with the cooperating teachers.

From the five preservice teachers observed during the Fall term part time student teaching, three were selected for more intensive study during the full time student teaching: one Caucasian male (Joshua) and one Caucasian female (Kelly) were selected the next portion of the study along with one African American female placed in a high school (Mira). All three names are pseudonyms to provide anonymity for these participants.

**Method**

The study was designed to describe the preservice teachers’ development of their TPCK throughout the teacher preparation program that integrated technology throughout the program and how they succeeded in teaching with technology in the actual classroom during student teaching. Yin (1994) suggested the use of multiple sources of evidence to ensure construct validity. The preservice teachers’ knowledge development of technology, teaching and learning, and content were collected using various questionnaires designed to gather participant information, observations, research field notes from attending all courses in the program, observations and interviews during student teaching, and preservice teachers
culminating work sample (a summative program requirement). The researcher recorded the nuances and richness of the context of the program, the courses and preservice teacher actions throughout the program using a research journal and collecting field notes. Interviews, pre- and post-observations during full time student teaching provided actual practice of preservice teachers’ TPCK as they assumed full instructional responsibility for their student-teaching classes while implementing their technology lessons.

Data Sources

Multiple data sources were used to obtain information toward answering the research questions. The primary data source for describing the preservice teachers’ TPCK was obtained from the student teaching classroom observations that included interviews before and after teaching including preservice teachers’ reflections on teaching with technology as documented in their work samples. Additional data sources were also collected from the classroom documents during fulltime student teaching such as lesson plans, students’ worksheets and activity documents, quizzes and assessment, and additional resources from the textbook and related materials to the topic being studied.

Questionnaires

Multiple questionnaires were used to gather information about the participants in the study. A Demographic Questionnaire was developed based on the National Educational Technology Standards for Teachers [NETS-T]
The questionnaire (see Appendix B) was divided into two parts. The first part of the questionnaire contained five categories matching the NETS Teacher Standards (2002):

- Technology operations and concepts;
- Planning and designing learning environments and experiences;
- Teaching, learning and the curriculum, Assessment and evaluation;
- and Productivity and professional practice.

The second part of the questionnaire obtained the background of the participants in terms of their knowledge on teaching and learning, mathematics, and technology. Besides this background questionnaire, another questionnaire (see Appendix C) on their proficiency with technology was used during the Summer term of the program. In addition, an open-ended questionnaire (see Appendix D) gathered their experiences in the program regarding six components of the program (courses, e-portfolio/work sample, microteaching, faculty, university supervisor, and cooperating teacher) influenced their development of TPCK. Their responses depended on how these various components helped them in preparing them to teach mathematics with technology.

### Academic Program Course Observations

The researcher attended all the courses throughout the program to gather data about the goals, design, and expectation of the courses. In addition, class artifacts were collected, including courses syllabi, assignments, projects, and electronic portfolio (e-portfolio) assignments to understand the context of the program. All the courses in the program were directed toward the student teaching
experience and the teaching of complete and well-planned technology lesson sequence. The academic course attendance provided an in-depth understanding of the program as the main context of the study. That understanding helped the researcher to prepare for the interviews and observations that were more focused on the purposes of the study by asking reasoned questions related to the program and its impact on them. In the interviews, the understanding of the program guided the researcher in prompting the participants in responding to questions within the context of the teacher preparation program specifically related to teaching with technology. The observation of the program also helped to direct the questions of the study and interviews related to the course work that participants completed during the program. During classroom observations, the researcher was able to focus on what the program expected of the preservice teachers during student teaching and contrasted the expectations with the practice of preservice teachers in the classroom. Attending the courses in the program allowed the researcher to become familiar with the preservice teachers, the faculty, and the university supervisors to establish a positive communication and working relationship with researcher.

Observations of Preservice Teachers

Throughout the program, the researcher used specific observational techniques to collect data on a wide range of preservice student teacher behaviors, to capture the variety of interactions and openly explore the development and implementation of their TPCK. In this study, two primary, yet different,
observation periods occurred, during part time student teaching (Fall 2004) and full time student teaching (Spring 2005). During part time student teaching, five teachers were observed with the purpose of identifying the three participants for the extended study during student teaching. During the full time student teaching, the observation focused on the three student teachers’ practices in teaching mathematics with technology and implementing their sequence of lessons with technology. These student teaching observations were focused on the pre-technology lesson, technology lessons, and post-technology lesson that the student teachers planned for teaching during student teaching.

Classroom observations were supported by relevant data such as the preservice student teacher’s lesson plans, intended class homework, assignments, quizzes, and projects. Other information related to the class and school sites, such as the number of computers, technical support for technology, the culture of the school in terms of technology used in teaching, and information about students’ demographics in the classroom were also collected. During the observations, the researcher was located in the back of the classroom and used a global scan method to record the actions in the classroom; the notes included the time, events, short notes about the event, and general comments about the instruction.

Preservice Teacher Interviews

Interviews were conducted formally and informally with the three preservice teachers selected for the Spring term to inform the intensive case investigations. Formal structured interviews were conducted during the pre- and
post-observations of each observed lesson taught by each student teacher selected for intensive study. All interviews were audio-recorded. Additional informal interviews were used to clarify information, facts, or behaviors if the researcher was unclear of some event or needed clarification prior to or after teaching. These informal interviews were not audio-recorded. Similar short informal interviews were conducted with faculty, university supervisors, and cooperating teachers to gain information in describing their support of student teachers in terms of the use technology in teaching mathematics.

The participants were interviewed prior to at the beginning of student teaching and throughout their student teaching. The purpose of interviews before student teaching was to identify the topics and plans for teaching throughout the student teaching experience, general teaching approaches, the use of technology in their teaching and a teaching schedule.

Formal interviews of the student teachers took place at their school during the student teaching before and after teaching. The interview protocol used before the observed teaching is available in Appendix E. The pre-teaching interviews gathered the goals, objectives, instructional approaches, and assessments planned for the lesson. The post interview (described in Appendix F) focused on having the student teacher reflect on the lesson and gathering their responses about certain specific behaviors during the lesson.

All formal interviews were recorded and transcribed as soon as possible after the interviews were completed. Each interview was recorded and collected in terms of the time and date, locations, topics of the lesson, teacher’s name, and the
context of the lesson in the unit. Notes were taken during the informal interviews and recorded in the researcher’s journal in addition to the global scanning format notes as mentioned earlier.

Technology Work Sample

An important feature of the effort to integrate technology throughout the teacher preparation program was the requirement for student teachers to teach mathematics with technology over a minimum of two to three days. As previously described, the program supported the student teachers in preparing for this requirement during Winter term, specifically in the SED 589 class. During this time, they planned and prepared the beginnings of their technology work sample. Student teachers were expected to teach the sequence of lessons during Spring term in their student teaching placement. The technology work sample was to be expanded to include the rationale, goals and objectives, calendar and assessment plans, lesson plans with reflections on teaching each lesson including copies of all student-documents, teacher-documents, worksheets, assessment instruments, and a detailed analysis and reflection on the student growth in meeting the unit objectives along with their analysis and reflection on their own growth in teaching with technology. This completed work sample provided the researcher with additional evidence to support the primary data gathered through the observations and interviews.
The Researcher and Researcher’s Journal

The researcher was an important part of the process in this qualitative study. The researcher’s approach in this study was that the participants, the mathematics preservice teachers, had knowledge about the topic being studied. So, the participants were the main source of the knowledge of how preservice teachers developed and practiced their TPCK in the context of teacher preparation program integrating technology. However, the researcher recognized that he was not able to distance himself from the topic and people being studied. This interaction between the researcher and preservice teachers created new knowledge. The researcher was also aware of the potential for bias throughout the one-year period of interacting with the participants, attending the courses, teaching some of the courses, and observing them in school sites.

The researcher used a journal to gather data from the beginning of the program while attending all courses. The journal provided a record of the events in chronological order. Any contacts, interactions, and interesting facts were recorded to balance the information from different components in the program during the study. Entries in the journal were used for further interviews to describe any uncommon behavior that occurred during the observations or attendance in the courses.

The researcher’s background was an important consideration in this study. The researcher taught secondary mathematics level for six years, three years in middle school and three years in high school not in the United States where the
study took place. He graduated with a teaching license for middle school and high school level teaching endorsement from a university that was used as a model for piloting the dilemma of who best prepared mathematics teachers, mathematicians or educators. The university adopted the idea that mathematicians trained with knowledge of teaching and learning were better prepared to teach mathematics than educators trained with mathematical concepts. After finishing a Master’s degree in the United States, the researcher studied educational technology with the emphasis on technology as a presentation tool only. After extensive investigation, the researcher began focusing on the roles of technology in student’s understanding of mathematical concepts.

As a member of two technology educator organizations, International Society for Technology in Education (ISTE) and Society for Information Technology and Teacher Education (SITE), that distributed much research on technology education, the researcher had the opportunity to interact and associate with different technology educators from different levels and interests. The associations with the technology educator organizations gave the researcher a chance to present and attend the conferences and workshops on technology in mathematics teaching. The researcher introduced specific software to mathematics teachers and general technology education for preservice teachers in two different departments at the university where the study took place, Computer Science and Science and Mathematics Education. During this teaching, he had the opportunity to learn and get feedback from students as to how specific technology might be applied in the classrooms.
Data Collection

The nature of this study was to explore the development of preservice teachers’ TPCK based on a detailed depiction of three preservice teachers. The multiple data sources resulted in a large amount of data. Systematic organization of the data collection was important for preventing the researcher from becoming overwhelmed by the amount of data and preventing the researcher from losing sight of the original research purpose and questions.

Three principles of data collection were followed in the development of the case studies: (1) use of multiple sources of data, (2) creation of a case study database, and (3) maintenance of a chain of evidence (Yin, 1994). The multiple sources of data provided for the triangulation of evidence. Data were organized and documented in a folder database. All types of relevant documents were added to the database, as well as narratives, and other notes from the class attendance and observations both on and off campus. The chain of evidence provided an avenue for the researcher to increase the reliability of the study, providing citations and connections to the case study database where the actual evidence was found. From each data collection activity, all recorded data were kept in the database of the research data. The database was systematically arranged so that date, locations, and names of related people in the study were kept in the records to maintain the chain of evidence on the database. Due to the important of triangulating data analysis on qualitative study, the different sources of the data were also filed into different folders.
Data Analysis

Blends of exploratory and general inductive approaches were used to make sense of the three case studies without imposing pre-existing expectations on the setting (Patton, 2000). Many different data sources were used in developing the cases. In general the data were analyzed through a collection of themes followed by subcategories gathered in concert with the context of the preservice teachers’ development of their TPCK and the components in the program such as the courses, work samples, faculty, student teaching, university supervisors, and cooperating teachers. Patterns and relationships that occurred in the data were identified between and within categories. Then the interpretation of the data from the context of preservice teachers’ TPCK development and teacher preparation program utilized all the themes, categories, and components in the program.

For the preservice teachers’ development of their TPCK, the data analysis concentrated on two main questions of the study: How do mathematics preservice teachers develop their TPCK in a subject-specific teacher preparation program that integrates technology throughout the program; and what features or components of such a program are influential to their TPCK development? The descriptions of the preservice teachers’ development of TPCK were derived from the questionnaires, courses attendance notes, courses documents (such as syllabus, assignments, and projects), informal interviews with instructors, student notebooks and e-portfolios, observations and interview along with documents (such as the Technology Work Sample) during full time student teaching. The primary data were the preservice
teachers’ background questionnaire. The student teachers’ written documents and materials during part time and full time student teaching were gathered in order to gather their progress in the program. The preservice teachers’ reflection on courses also provided information about how they developed the meanings and knowledge of the courses taught in the program.

To obtain the Spring term student teaching general teaching style, classroom management, and overall teaching environment, one observation was conducted before they taught with technology, when teaching a non-technology class. The major data source to see how the preservice teachers practiced and implemented their technology lesson plans was gathered through observations and interviews pre- and post-teaching. The consistency of their teaching strategies was identified from the last phase of observation in non-technology lessons. The data from two interviews were analyzed to obtain each preservice teacher’s conception about teaching with technology, the reason for selecting specific actions in the lesson, what they thought after teaching with technology, and any modifications they planned if they were to teach the same lesson in the future.

In identifying important and influential components of the program, data analysis was conducted with a focus on the research objectives, the literature review, and multiple readings and interpretations of the collected data. The course attendance documents were then used to confirm that these important components were emphasized in most courses and potentially influenced the preservice teachers’ development of their TPCK. Courses syllabi, assignments, handouts, and projects determined the goals and objectives along with the expectations for student
teaching that were needed to identify the context of each participant’s development and implementation of TPCK.

The literature review identified six components as the main features that influenced preservice teacher’s development: course work, microteaching, work samples, instructor, university supervisors, and cooperating teachers. These six components were used to generate other components that could influence the preservice teachers’ TPCK and descriptions of how those components affected the preservice teachers’ development of TPCK.

To summarize the three cases, a general description of the study was described with a larger view of how the preservice teachers developed their TPCK. Two research bodies were used to guide the analysis of the preservice teachers TPCK during the student teaching experience. The first research body used the four central components of TPCK described by Niess (2005): (1) an overarching conception of what it means to teach mathematics that integrate technology; (2) knowledge of instructional strategies and representation for teaching mathematics with technology; (3) knowledge of students’ understanding, thinking, and learning with technology in mathematics; (4) knowledge of curriculum and curriculum materials that integrate technology in mathematics. The second research body was the five stages of Apple Classroom of Tomorrow (ACOT) model of evolution of thought and practices, (1) **Entry**, Learn the basics of using the new technology. (2) **Adoption**, Use new technology to support traditional instruction. (3) **Adaptation**, Integrate new technology into traditional classroom practice. Here, they often focus on increased student productivity and engagement by using word processors,
spreadsheets, and graphics tools. (4) **Appropriation**, Focus on cooperative, project-based, and interdisciplinary work - incorporating the technology as needed and as one of many tools. (5) **Invention**, Discover new uses for technology tools, for example, developing spreadsheet macros for teaching algebra or designing projects that combine multiple technologies. (Sandholtz, Ringstaff, & Dwyer, 1997).
CHAPTER IV

RESULTS

Introduction

This chapter presents the results of the study and discusses how the present study’s results relate to the research questions. The primary question concerned how the mathematics preservice teachers developed their TPCK during a one-year teacher preparation program that integrated technology throughout the program. The focus of the study on the development of preservice teachers during the program was divided into two aspects, their understanding of TPCK and their practices of TPCK during student teaching. The secondary question was: “What were the components in the program that helped preservice teachers develop their TPCK?”

The results of the study are presented in two sections. The first section is a description of the three cases of the preservice teachers that includes the background of preservice teachers related to TPCK, the development of their TPCK during the program, their practice of teaching mathematics using technology during the microteaching, part time and fulltime student teaching. In addition, the roles of several components in the program that helped each preservice teachers developed and practiced their TPCK are also discussed. The second section of the chapter presents a cross analysis of how the three preservice teachers practiced teaching with technology. In this section, two main bodies of research were used: Four central components of TPCK, (1) an overarching conception of what it means
to teach mathematics that integrate technology; (2) knowledge of instructional
strategies and representation for teaching mathematics with technology; (3)
knowledge of students’ understanding, thinking, and learning with technology in
mathematics; (4) knowledge of curriculum and curriculum materials that integrate
technology in mathematics, (Niess, 2005); and the five stages of Apple Classroom
of Tomorrow (ACOT) model of evolution of thought and practices, (1) **Entry**,
Learn the basics of using the new technology. (2) **Adoption**, Use new technology
to support traditional instruction. (3) **Adaptation**, Integrate new technology into
traditional classroom practice. Here, they often focus on increased student
productivity and engagement by using word processors, spreadsheets, and graphics
tools. (4) **Appropriation**, Focus on cooperative, project-based, and
interdisciplinary work - incorporating the technology as needed and as one of many
tools. (5) **Invention**, Discover new uses for technology tools, for example,
developing spreadsheet macros for teaching algebra or designing projects that
combine multiple technologies. (Sandholtz, Ringstaff, & Dwyer, 1997).

**Individual Case Studies**

Multiple cases were developed from the summary and analysis of various
data sources in order to provide a rich description of three specific student teachers’
development of TPCK during the program and their practices of teaching
mathematics with technology during the microteaching, part time and fulltime
student teaching. Each case was presented into three different time periods, prior to
the program, during the course works, and during student teaching. The three
student teachers were selected to represent the population of the mathematics
preservice student teachers in the program during 2004-2005. Mira and Joshua
taught in a high school setting and Kelly taught in a middle school setting.

Mira

Mira’s TPCK background

Mira was a preservice teacher who obtained her Bachelor’s degree in
Mathematics from the same university as the teacher preparation program. Her
knowledge of mathematics was typical for the preservice mathematics teachers at
this university in that her degree included all the mathematics courses required for
admission to the program and she achieved a minimum grade-point average of 3.0
in the last 90 quarter credits of graded undergraduate work. She had experience in
teaching as an undergraduate teaching assistant in algebra and trigonometry at the
college level during the last year of her Bachelor’s degree program. This
experience involved mostly tutoring rather than preparing the class, giving
instruction, and overseeing the assessment. Her educational philosophy indicated
that all students needed to be involved in the classroom instruction. She believed
that all methods of teaching should be used in different types of instructional
situations. For example, she believed that lecturing should be used for introducing
new concepts, that lab and hands-on activity should be used to give student
experiences with the concepts, and that repetition was needed to help the students
place the concepts in their long-term memory. She believed in student-centered
group activities where all members of the class worked together on an activity or idea.

In terms of technology, she had basic skills and knowledge of the majority of the technology used in teaching, such as graphing software, geometry software, multimedia still and motion presentation, and webpage design. She had proficiency in using graphing calculators better than other technologies in mathematics education. Formally, she had not taken any computer courses in the university or outside the school. She had little background in taking courses in teaching mathematics or related courses in teaching before entering the program. The only two courses she took related to teaching were SED 309, a field practicum in mathematics classroom for elementary/ middle level, and SED 409, a field practicum in mathematics for middle/ high school level. In those two courses she was required to be in the classroom for at least 54 hours each term to experience and observe the classroom instruction. No university class instruction accompanied these courses.

Mira’s TPCK during the program coursework

Mira took the technology foundations course (SED 412) during the summer as part of the technology sequence in the program. With the summer coursework, she found herself reacting positively to the role of the courses in helping her prepare for teaching specifically teaching mathematics with technology. Overall, her performance and achievement in this course were satisfactory. She had difficulty in completing the assignments in a timely manner at the beginning of the
term due to personal reasons preventing her from attending the beginning of the course on the first two days. She also had difficulty with the electronic portfolio assignment, only completing about two-thirds of the requirements at the end of the term. Part of the difficulties she faced was in designing a webpage that demonstrated her different exhibits of expertise with technologies such as PowerPoint, Imovie, spreadsheets, and calculators or other probeware devices. However, she was above average in her completion of the other assignments in the class, demonstrating her skills and knowledge with calculators, spreadsheets, presentation software, and video editing.

During Fall term, Mira’s performance was about average, particularly with the pedagogy class that included microteaching and a technology emphasis (SED 574). She completed all assignments in a good fashion, even though sometimes she needed more time to complete the work. She was enthusiastic about learning about the technology taught in the program, such as Geometer’s Sketchpad, spreadsheets and calculators. She planned her lesson for teaching on the topic of functions in her group in this class. Her microteaching practice adequately presented the lesson on functions.

Mira’s part time student teaching experience was at a new middle school that had a high-tech computer lab with several software applications including Geometer’s Sketchpad. Her student teaching in this class consisted of teaching eight lessons for her first work sample. When teaching these lessons, she had the opportunity to use Geometer’s Sketchpad to explore pi (π) with her 8th graders twice. The first technology lesson began with a short introduction about pi and
*Geometer’s Sketchpad* by talking to the students before moving to the computer lab. She made a last minute decision not to provide the students with a copy of the worksheet prior to going to the lab because she used so much time on the introduction of *Geometer’s Sketchpad*. She realized at the end of the lesson that her decision created some chaos for the students because the lab setup was in a circular shape not allowing her an appropriate place to demonstrate the worksheet completions for the students. Another difficulty was that one third of the students had not memorized their student identification numbers needed for logging onto the computers. Despite the disruption created by these problems, the class was considered successful by the end of the session since the students were successfully able to construct a circle on their screen using the appropriate tools.

Mira’s second technology lesson was in a unit on circles, identifying central and inscribed angles. This time, she explained the worksheet in the previous class, before the students went to the computer lab and reminded them to bring their identification numbers to log onto the computers. The class went smoother, allowing students to construct, measure, and compare the values of the two angles.

During Winter term, she completed her microteaching over a longer time period than during Fall term. She decided to use spreadsheets in teaching word problem solving in systems of two linear equations. She provided a short lecture about the problem and then used a question-and-answer technique to guide the students in tackling the problem using a computer spreadsheet solution. However, the discussion took the students in different directions and created confusion among them. During the discussion after the microteaching, she realized her actions were
ineffective in guiding the students in the technology activity. She did not realize that spreadsheet was different than calculator in its ability to process the input of the equations. In calculator based, an equation has to be express in a “$y = ax + b$” form so that the calculator will be able graph that equation, while in spreadsheet, the equations did not generate the graph until it is entered into cells with real numbers of “a” and “b” then generate the graph from the cells that referring to the independent and dependent values.

**Mira’s TPCK during student teaching**

During the fulltime student teaching, Mira was placed in a high school in the same city as the university. The school system held high standards for achievement from the students. She was placed with a cooperating teacher who graduated from the same program a few years earlier. She taught a 10-lesson probability unit for her work sample unit in a yearlong algebra course. The observations and interviews were focused on this class and her three technology lessons were outside the work sample, involving systems of linear equations.

The class consisted of 27 students, mostly freshmen with a few sophomores and juniors. The class met Monday through Thursday from 7:45 – 9:20 AM, the first class of the day. The technology lessons were taught in the early part of the term before she taught her work sample lessons. She also taught with technologies several additional times in addition to the work sample and technology sequence of lessons. In all the student teaching, she assumed full instructional responsibility of this class for six weeks.
Mira’s first technology lesson in her technology sequence was an introduction to the graphing calculator and how to use it to solve a system of two linear equations. The students had learned on how to solve such systems by hand in the previous class. She borrowed the calculators from the university so that all the students could have the same calculators for their work. She began the class with the usual classroom routine by returning the students’ tests from the previous lesson, reviewing the answers for the problems, and answering questions about the test; this process lasted about 15 minutes. She continued the lesson by informing the students that the class was going to use calculators to solve similar problems that were done in the previous lesson without calculators. She did not explicitly mention why they were to going to use the calculators however; the students did not ask why either. Her responses during the interview suggested that she had just changed the technology being used in the lesson. The spreadsheet that was initially included in the lesson plan was changed to the use of calculators. With limited preparation and practice with the calculators, the first problem she dealt with at the beginning of the lesson was in distributing the calculators that she had borrowed from the university. She laboriously distributed the calculators to all the students by calling each student’s name and handing them a calculator, asking each student to sign a checkout sheet and take the worksheet from her desk. The students who received their calculators early in this process were confused about what to do while they waited. This process took about 15 minutes resulting in a loss of important instruction time. When she was asked why she distributed the calculators in this way she replied:
I really wanted to make it clear at least today that it’s important that these calculators get back and that I keep track of them. I didn’t actually say that but I think they understood by them, checking them out, it’s important that it comes back.

The lesson continued with the introduction of the capabilities of the calculator that they would be working with for the remainder of the class period. She projected the image of her calculator on the overhead projector so that the students were able to see how their screens should look. The introduction included an identification of the operation signs, entering formulas, and changing the window size using the zoom features for handling cases where the graph was not visible on the screen. The worksheet consisted of five problems as an exercise to become familiar with the calculator. The students solved the first problem with Mira leading the class using her projection of the calculator. Several students found some errors on their screens and were told to ask their neighbors before raising their hands to ask the teacher. For the remaining of the class, the students worked in self-assigned groups of two or three. Several students finished their worksheets 10 minutes before the class ended.

About three minutes before the end of class, Mira gathered the attention of the class for a discussion on the use of calculators with these problems. Several students gave different responses about the importance of the graphing calculator in looking at graphs of different equations in a short time period and finding the intersection of the two graphs at a precise point. Others mentioned that there were many keys that were small making it hard to find the feature they needed to solve with the problems. One student said the calculator was not fun because there was
no game on it. The class ended on time and students returned the calculators, signing off on the check off sheet.

The next day, Mira distributed the calculators in the same laborious way but she managed to complete it in half the time she spent on the previous day. She used a lecture-discussion approach to introduce the calculator; through questioning of both volunteer and non-volunteer students, she gauged whether the students were able to use the calculators appropriately. She guided the students in seeing that they needed to translate a written problem into a mathematical form in order to see how they needed to enter information into the calculator. The example of the problem was:

Zelda wants to have business cards printed. One style will cost $25 plus 2 cents per card. Another style will cost $10 plus 5 cents per card. For how many cards will the cost be the same for both styles?

In this problem, Mira helped the students identify the $x$ as the number of cards and $y$ as the total of the cost. In this problem, the calculator representation of the number of the first style of business card was to be the $x_1$ and the total cost was $y_1$; accordingly the number of the second card was to be $x_2$ and $y_2$ as the total cost of the second card. The conversion of the units was identified as a critical issue that the students had to be aware of because both dollar and cents units were being used in one problem. After about 15 minutes, the problem was solved for the class using the blackboard and Mira’s calculator projection.

Following this presentation, the students were expected to work in groups of two or three to solve the other two problems. The students finished with the two problems in about 15 minutes. The students were generally active in their group
work except for a few students in the back row who sometimes were disruptive as they ignored the teacher. Several groups had raised their hands indicating that they needed help. Mira spent most of the time circulating from group to group to make sure that all students were on task and answer questions regarding the problem and the calculator.

Mira distributed the quiz for the section on solving systems of two linear equations using the graphing calculator. The quiz was planned to be given when the students finished all the worksheet related to systems of linear equations during the last 35-45 minutes of the class. However, only about 20 minutes remained when she distributed the quiz. The quiz worksheet contained two parts. The first part was a direct application of finding the solutions for systems of two linear equations using the calculator. Students were asked to show their work and the screen of their calculator, draw the graph in a dedicated box next to command they entered in the calculator, and write the solution. She said that the students were only required to do the first three problems and do the extra credit problems as an optional. Due to the limited time provided, only a few students attempted the extra credit problems. Two students did manage to complete one extra problem correctly. Several students finished the quiz in 10 minutes. The quiz ended when all the students finished and placed their work in the basket next to the teacher’s desk.

During the interview, Mira explained why the time to solve the quiz was short, only about 16 minutes instead of 40 minutes. Part of the reason was that she noticed several students had not finished with the practice worksheet problems about using calculators to solve systems of linear equations given at the beginning
of the class. So, she waited until all the students finished the worksheet. She explained the reason she waited until the time was so short because that it would not be fair for the students who were not finish working with the worksheet to stop and do the quiz. So, after all students returned the worksheet to her, she distributed the quiz. She added that she actually planned to ask students to do an extra problem on the second and third pages but she did not do so because the time was so short. She finally decided to tell students to do the first page only - the three practice problems using the graphing calculator. During the interview, when she was asked whether her students understood the purpose of using the calculator for the lesson, she replied that most likely the students did not. Part of the reason was because she did not introduce the lesson by telling the students about the importance of using the calculator during the lesson.

With respect to assessing her students’ performance and achievement during technology lessons, she mentioned that she did not really assess how technology was being used in the class; rather she assessed what concepts the students learned from the technology experience. Mira indicated that the result from the assessment on the technology lesson was encouraging because students demonstrated that they learned how to use the graphing calculator well. Only two students earned a score less than 10 points of the 15-point quiz. She reported in her reflection that using graphing calculators helped the students to visualize what an intersection point was and connected more clearly to the solution of a system of equations. Also from an informal survey from her students, her students noted that the graphing calculators made it easier to graph once they knew how to enter the
equations. The problem that her students still had was not from following the step-by-step commands with the calculator to find the solution; rather her students had difficulty interpreting and translating word problems into a form that was well-matched with the calculator commands. An example of this problem was when students were given this word problem:

The perimeter of a rectangle is 180 ft. One-fourth of the length is the same as twice the width. Find the dimensions of the rectangle (length and width).

In this problem, her students struggled to put the word problem into a mathematical form before entering the equation into calculator. Only a few students raised their hands when she asked which students found the correct answer to this problem. She realized that her students were less familiar with how to approach and interpret the problems than in using the calculator to follow the steps to solve the problem. When she was asked if she was given a time to teach the same topic in the future, she responded that she would give some additional instructions on how to interpret and translate these problems into mathematical forms.

Mira said that Fall and Winter technology and pedagogy courses were what helped her the most to teach with technology due to her limited background of technology skills and knowledge prior to entering the program, particularly in learning her mathematics subject matter. She learned about Geometer’s Sketchpad when she started the program but she had learned the basics of spreadsheets two years previously. The course work was the first one that Mira mentioned when she was asked about the roles of several influential components in the program.

I think that from those all the course works that helped me the most was the pedagogy and technology sequence courses. (Referring to SED 512, SED 574, and SED 589)
She recognized that these courses were very important for her because they gave a lot of ideas on how to integrate technology in mathematics classroom, get acquainted or familiar with new technology such as spreadsheet, geometer sketchpad, Imovie, and webpage software, and also provided her opportunities to practice to incorporate different technologies with her teaching styles. She did not indicate the different roles among those three sequence technology courses. Her responds about the roles of other courses were positive and informative as well such as:

The methods course was just for the work sample. I mean it was helpful for the work sample but I can not use it directly to my teaching… I mean some of the activities they did in class were helpful to get ideas basically but the actual assignments and lessons, I do not know when I will be able to use those. Pedagogy course was helpful as well as the Math materials lab in the summer that was great too.

She did not mention anything about the role of her cooperating teacher. However, she wrote in her reflection that her cooperating teacher helped her realized the important of introducing the new materials through the concepts covered before. Besides recognizing the role of her university supervisor in helping her complete the work sample, she also mentioned about her university supervisor role in helping her preparing assessment for her lesson such as identifying what are important thing in the assessment that need to be considered.

Mira found that microteaching was helpful for her in practicing the technology lessons, but she found these experiences as somewhat far from the reality of the classroom of students. In microteaching, she noted that her peers were all graduate students with strong backgrounds in mathematics and technology
compared to actual students in high school or middle school where the students had only basic skills and novice abilities in mathematics and with technology. At the end she suggested that the program should give more training on classroom management because that was what she needed the most as she mentioned in an interview:

   It would be better if we went to a classroom and we borrowed somebody’s class for a day and did that instead of doing peer teaching because in peer teaching, everybody in that class are math teachers and they are the perfect student already.

Summary of Mira’s TPCK

Mira’s background in mathematics was adequate given her admission to the teacher preparation program and the level of mathematics courses taken in her undergraduate degree. Prior to her entry to the teacher preparation program, her technology background was limited to general use of the Internet, calculators, and word processing. However, her technology skills and knowledge increased dramatically during the program. She not only learned several new technologies in the program but also integrated, practiced, and taught with them in her mathematics classrooms. At the end of the program, Mira’s performance demonstrated that she adequately completed all the program requirements and demonstrated gains in knowledge of technology, pedagogy, and subject matter. However, when she was asked about the role of technology in the mathematics classroom, she responded that technology was best used to extend the students’ knowledge about mathematical concepts, after they were taught with paper and pencil.

   I would probably use [technology] as more of a supplement for the students after they have already learned a skill then to show them [that] this is how
you could do it with a calculator. Or this is how you could do it with the Sketchpad - learn how to do constructions on paper and pencil, now you can learn how to do it on the computer.

Her expression suggested that she wanted to use technology to supplement students’ learning of the mathematics and that technology’s role was to extend the topic that was previously discussed using different strategies, such as hands-on activities or traditional lecture-discussions.

Her comprehensive teaching experiences in the Fall and Spring terms were valuable for her. She responded in several occasions that if she had been given more time to teach, she could improve her teaching. She explained in her reflection the two aspects of teaching where she had made the most progress:

Classroom management and preparedness are elements of teaching where I have felt growth this term. Managing the classroom was something that I had minimal experience implementing because my first class was near perfect in that area. This term, my algebra class in particular challenged me and helped me to be firm and find my authority as a teacher. Consistency and definition are my goals for classroom management. To be prepared is for me to practice and plan more than I expect will be enough.

Overall, she was pleased with her accomplishments in her student teaching especially in the technology lessons.

Several issues were identified in the observations and interviews during her student teaching. First, for the most part, she followed her teaching instructions as written in her lesson plan. In her responses to the researcher, she often indicated that she did not have a specific rationale or reasoning behind the lessons. In one instance when asked about whether her students knew why they were given calculators to solve the problem in her algebra class, she replied that she did not think that she needed to ask her students that question; however, in the post
reflection on the lesson, she wished that she had time to ask them about that question in the next class. When assessing students’ achievement or performance when technology was involved in the lesson, she responded “I don’t really assess how they are using technology. I assess the concept of their learning through using the technology.” Yet, when the follow up question was asked as to how she assessed the process of student learning of the mathematics concepts using technology she did not have a specific answer. A third issue that was apparent in her classroom was the lack of an overarching conception about teaching with technology. Mira’s plan tended to end each day without making connections with other lessons. When she was asked what the next class would be, she responded that she had it on the lesson plan. Even though she wrote the lesson plan already, she still did not have a clear description of a major objective for future classes. She knew what materials she was going to teach with but she lacked knowledge and experience to describe the overall goal for the class. A final issue with her instruction was with her limited skills and knowledge of integrating technology into different instructional schemes, such as using technology in warm-up activities to begin a class, introducing new concepts with technology, providing students’ practice with technology after instruction with certain topic in mathematics, or engaging the class in a review and overview of previous topics, with feedback from previous topics or independent student practice as enhancement program for specific students. Mira’s teaching practice with integrating technology was limited to student practice after the topic was discussed on previous lesson.
Even though Mira’s overarching conception of what it means to teach mathematics with technology was limited, she did understand how to transform instructions into step-by-step classroom instructions. Besides her recognition of the importance of acknowledging students’ thinking and learning by providing a suitable technology and designing an appropriate quiz, she had difficulty in organizing the level of problem difficulties on the worksheet. She reordered the number of the problems on the worksheet at the last minute. Right before the class started, she realized that the difficulty level was not in sequence from simple to more complex problems. In terms of the knowledge of curriculum and curriculum materials, she demonstrated the ability to select problems that were best displayed by the technology being used and the levels of students’ ability in using the technology.

In general, she recognized that the technology was a tool to teach mathematical concepts; however, her actual practice in teaching showed that she was not comfortable in integrating the technology to its full potential role for teaching mathematical concepts. She used technology merely to try a different way to solve problems that were similar to the ones completed previously in a non-technology approach. This behavior may have been a result of her limited technology background and learning experiences with the particular topics. With limited technology background, she tended to demonstrate the use of technology as the lesson plans indicated. She did not allow students to explore the technology on their own, thinking they might have problems that she would need to troubleshoot.
Her limited technology background in some ways might also have influenced the amount of time and the kind of technology use in the classroom.

She knew how to demonstrate the technologies (because she was in control of the flow) and how to explain solving the problems with calculators, but she lacked an understanding of the reasoning used in certain methods when solving problems with calculators. The solution of systems of two linear equations as the intersection of two lines was an example. While the intersection had an \( x \) and \( y \) value, she did not clarify what those values meant in relation to the problem being solved. Her limited experience in teaching the topic influenced her instruction style toward a tendency to follow the lesson plan exactly as written, rather than allowing for student input that might shift the direction of the lesson. She also emphasized the use of the technology as a tool to check solutions rather than to investigate new concepts. Her belief about actively engaging the students in the lesson was observable as she assigned them to work in groups of three or four to finish a worksheet. Then she assigned the representative of the group to present the group’s answer on the overhead projector in front of the class.

Regarding the roles of several influential components in the program, she stated that the course works were the main sources that prepare her to teach with technology. Specifically, the sequence technology courses thread was very important for her in helping her develop her TPCK during the course as well as during student teaching. However, she was unable to state the details roles of each course in the program. She was preoccupied by the idea that when you were taking
the class like a student; you were just thinking that I had to get something done by
the end of the term.

Joshua

Joshua’s TPCK background

Joshua completed his undergraduate degree in Mathematics with a
secondary teaching option from one of the colleges in the Northwest. His written
philosophy in his first work sample described his belief about the role of the
teacher as useful for providing an introductory explanation of the ideas and then
assigning the students to work on problems, extending and repeating the ideas and
patterns. He also believed that the role of the teacher was as a guide for the
students’ thinking who probed the students’ thinking. This method allowed students
to realize where they had misconceptions and to correct these problems through
discussion with their peers. He also emphasized the importance of communicating
with the students in order to find out what interested them; then he planned to
incorporate those interests into the instruction in some fashion. In regards to
instruction, he believed that effective teachers must incorporate as many learning
styles as possible into their instruction. The learning styles that he planned on using
the most were oral, visual, and hands-on learning. He strongly believed that by
incorporating these styles he was able to reach more students in a manner that
allowed the students to build a stronger understanding of the material.

His technology background was stronger than the rest of his classmates. He
took several computer courses in his undergraduate program from the computer
science department, including programming and an introduction to the analysis of programs. He reported that he had a strong proficiency for using this information and probably for teaching with several technologies: word processing software, spreadsheets, online source-searching, and the use of graphing and programmable calculators. He also had proficiencies in other technologies for his own use only: graphing computer software, multimedia software such as *PowerPoint*, video and still images editing, and web editing software. His response to the questionnaire regarding his competencies and beliefs about technology in alignment with the national technology standards for teachers showed that he had strong skills with most of the standards: basic operations and concepts of technology, planning and designing lessons with technology, use of technology in teaching and learning, and evaluating and assessing students learning with technology. Though his skills and abilities using technologies were shown to be exceptional, he responded negatively toward the following issue statements:

- Mathematics teachers need to know how to utilize technology-based materials to plan for their lessons, technology implementation in the mathematics curriculum is important for students in their learning activities,
- It is important for teachers to apply technology resources to facilitate a variety of effective assessment and evaluation strategies, the use of productivity tools (i.e. *Microsoft Word*, *Excel*, *PowerPoint*, etc.) will positively affect the quality of teaching practice,
- Teachers should continuously be informed about new technology tools for their professional development.
The reasons for his negative responses were unclear. One possibility may have been his lack of experience learning with technology in his own education and his limited experience in teaching. Even though technologies had been part of his life and school, Joshua had no experience in using any of the technologies he knew for teaching mathematical concepts prior to entering the program. He was enthusiastic when he discovered that the program worked to help him teaching mathematics with different technologies.

Joshua chose his undergraduate program majoring on mathematics with the option of secondary teaching track. Besides the mathematics courses during his undergraduate years, he took several courses from the program related to teaching, such as methods foundations for teaching mathematics and mathematics materials and laboratories. In addition to his background with courses related to teaching, he also had informal teaching experiences during one year. Joshua understanding about teaching and learning was that teachers have to use different method of instructions. He felt that using various methods facilitated the topics so that it met the needs of student with different type of learning styles. This understanding implied that teachers needed adequate knowledge to decide whether or not some adjustments in the teaching style were needed in order to reach the optimal number of students. In support of his statement, Joshua reported about his experiences when he taught a unit on systems of linear equations:

The class had discussed the substitution method, and the teaching style used was an inductive approach. The students responded to the lesson in such a way that I felt they understood the underlying concept. However, after viewing the assignment I had given them, I realized that many of my students were only able to apply the process of solving a system of linear equations instead of the understanding the underlying concepts.
After he identified the problem, he decided to re-teach the idea of substitution, but instead of using the same teaching style, he chose to use a hands-on approach. The new approach in the lesson seemed to allow the students to grasp the concept instead of just the process of solving the problems only. Joshua strongly believed that in order for teachers to teach effectively and efficiently, they needed to take into consideration the entire teacher knowledge base: content, pedagogy, and learners. With the integration of these three knowledge bases, he felt the teacher was able to address the misconceptions that appeared during the lessons.

Joshua’s TPCK during the coursework

Joshua started the program in summer term by taking the first technology course requirement in the program, Technology Foundation for Teaching Mathematics and Science (SED 412). He easily followed all of the topics discussed in the class because he had a strong background with most of the technologies incorporated in the course. However, he was very enthusiastic to see how the different technologies with which he was familiar could be used to teach mathematical concepts in an appropriate way that focused on improving student understanding. He was active in all discussions related to the technology used in the classroom. His interest was focused mainly on how the selected technology in the course might solve multiple mathematical problems. He did not comment much when it came to the question of ways to implement the lesson using technology to improve student understanding of mathematical concepts. Joshua did well in finishing all the assignments during the first technology course that included
multiple technologies including *PowerPoint*, *iMovie*, e-portfolio, spreadsheets, and calculators. The summer technology course also required Joshua to design a short technology lesson that was an extension of the resource cards that were collected during the summer term using a different technology.

During his part time student teaching, at the beginning of Fall term, Joshua taught in a middle school that had approximately 300 students in K-8 grades. The school had few resources and 90% of the students qualified for the free-and-reduced lunch program. The unit of instruction chosen for his part time student teaching dealt with one step algebraic equations. The purpose of the lesson focused on two advantages. The first was to enable the students to solve real-world problems that could be represented using simple mathematics. The second area of emphasis was to engage the learners in thinking differently than what had been required of them in the past in order to enhance their understanding of mathematics; he also hoped to provide them additional opportunities for more abstract thinking. Joshua did not use any technology during his part time teaching since it was not required for him. However, he had a chance to try several new approaches in his lesson, a group activity combined with whole class discussion where students came up in front the class to show their group work while also explaining their reasoning. His goal in this method was to show how different methods were successful in transforming different concepts. Another important experience for him was time distribution. On more than one occasion he ran out of material to teach in the available time. In other words, he finished his lessons earlier than what he planned due to students’ motivation in learning the topic. As a
result, he was nervous thinking about what to do with his students when a significant amount of time remained. Fortunately, he managed to identify an activity for his students to complete in the available time. He realized how important preparation for unexpected situations was. He responded about these occasions:

I now realize that at all times a teacher must have a back up plan, or filler assignments for cases just as in the described situation. I have vowed to always have one or two assignments to grab in emergencies.

Besides the part time student teaching, he was also taking the Fall term technology course, Technology and Pedagogy I. Joshua was eager to learn when it came to technology. He frequently participated during the discussions as a result of his strong background with technology. Part of the assignments for the course involved designing and teaching a short technology lesson in front of his classmates. Joshua taught a lesson on solving systems of linear equations using multiple representations. He organized his lesson in a deductive style where he, as the teacher, gave the general rules for solving the problem and then explained an example of how to use the rules or formulas. At the end the students practiced similar problems that he provided. Joshua used real-world problem solving with an application that involved the use of graphing systems of equations. The classmates responded positively with Joshua’s microteaching activity. He planned to use the same lesson in his Spring term student teaching.

During Winter term, Joshua took another technology course, Technology and Pedagogy II, which was more focused on preparing the students for student teaching with technologies such as spreadsheets, calculators, and Geometer’s
Joshua decided to use the same topic he did during Fall term microteaching since he knew that the topic would be taught in high school, Algebra I class, where he would be teaching. The difference in the Winter term lesson compared to the one during the Fall term was the technology used. During Fall term, Joshua used spreadsheets to solve the systems of linear equations while during Winter term, he used calculators. The major project for the term was to develop a sequence of technology lessons and revisit and finish the e-portfolio project begun during Fall term. Joshua did well in his e-portfolio project even though there was still a lot to improving the content and design. He completed all the documents required as part of the technology sequence project including the teacher’s documents, assessment plans, worksheets, and technology quiz. He was confident with what he prepared for the Spring term student teaching especially teaching with technology.

Joshua’s TPCK during student teaching

Joshua was placed in a large high school in an urban setting with population of around 1,500 students with a wide range of ethnicity and 50% of the student body qualifies for the free-and-reduced program. The school also had, on average, a computer lab for each department in the school. The large number of Latino and Russian students had a large impact on the school, in that a variety of English as a Second Language (ESL) classes were available to meet the needs of the various students. His classroom also had a wide range of students. Among the 34 students in the Algebra class, 33% were minority students. Also 10% of these students were
on an Individualized Education Program (IEP). The classroom contained a large blackboard along one of the walls, one overhead projector for most of the written instruction. The class also had a set of 36 TI-83plus calculators.

Joshua’s technology lessons were part of his Spring term work sample that included 16 days of instructional plans including quiz and review. The topic of work sample was on systems of linear equations. The unit started with the basic ideas around systems of linear equations and then progressed to more advanced topics. The unit began with the students exploring the possibility of different solutions for systems of linear equations. Students then were introduced to the use of the technology to investigate a graphing method for solving systems of linear equations. First, the students investigated this method by hand (with paper and pencil) and then compared it with the use of the technology; at this point, they were prepared to discuss the role of technology in mathematics. At the end of the unit the students were given a variety of real-world problems as an opportunity to manipulate mathematics word problems using a system of algebraic equations.

Joshua’s first technology lesson started with a basic introduction of operating the calculator followed by features and capabilities for completing calculation and creating graphs. This technology lesson focused on an introduction to the use of the calculator for finding the intersection of two linear equations. Joshua previously introduced the concept of the intersection of linear equations and methods of solving systems of linear equations in a non-technology lesson using a deductive approach. The students had learned basic procedures for solving system of linear equations in the previous class, symbolically and graphically. He provided
the students with the formulas followed by some examples of the problems and solutions. Then, the students did some exercises with similar problems from the worksheet. After this experience, Joshua gave the students homework on similar problems; the problems were corrected in the next class session. When students were assumed to have mastered the methods of solving systems of linear equations with paper and pencil, he then introduced the calculator as a tool that could also be used to solve the previous problems from the non-technology lesson.

Joshua introduced several features of the calculator that were most commonly used in solving system of linear equations such as entering formulas, setting the window, zooming in and out, and finding the intersection point of lines in selected graphs. Joshua did not explain to the students why they had to use the calculator instead of paper and pencil. The students also did not ask the reasoning behind the use of calculator. He chose two problems that had already been discussed in the class without technology. Then he demonstrated for the class a method to solve one of the problems using the calculator. The students followed his instructions step-by-step to solve the second chosen problem. After students had the idea of solving the system of two linear equations with the calculator, he provided them with an additional worksheet to complete during the class. No specific arrangement for the classroom or group work was planned, so students worked on their own to solve the problems. Some students initiated a discussion with the students who sat next to them to compare their solutions. However, one of the problems that Joshua had chosen did not use two linear equations; rather, the problem used one linear and one quadratic equation. So, the intersection of the two
equations was two points. Several students did not see the graph on their screen and some of them got error messages on their screen. To get the point across, Joshua finally called for the students’ attention when after about 10 minutes none of his students was able to find the intersection. Joshua demonstrated again how to get one of the intersection points but not the second one. He did not mention his reason for showing the students only one intersection point. The class was shorter this day because of the standardized testing schedule that required the students to use the computers. The class finished about 30 minutes earlier and students moved to the computer lab to do their practice test on algebra using the school’s mathematics software.

In his technology introduction lesson, Joshua reviewed the lesson quickly trying to squeeze the lesson into a shorter amount of time than his lesson plan. This limitation did not allow adequate time for the pre-assessment to be completed. Another problem with the lesson was the fact that he did not have an overhead screen for his calculator. This lack of focus resulted in many of the students becoming lost. Joshua had to fix the problems on students individual calculators since the students had different errors in their procedures. In his reflection, Joshua was not happy about what he did on the first technology lesson:

I think the lesson would have gone much better if I had the overhead screen. Tomorrow I will have a screen to teach the main technology lesson on graphing systems of linear equations. I think this will allow me to slow down my lesson as well as be able to check for student understanding more frequently and effectively. It was a mess teaching on how to use technology without something for the students to follow along with the instruction that was given. So having the overhead screen is a much-needed tool.
In the second technology lesson, Joshua continued the topic of solving systems of linear equations. This time he had a projector for his calculator and seemed to be more prepared than he was for the first lesson. During the first 20 minutes, Joshua reviewed the previous problems and providing step-by-step instructions in how to solve the assigned problems from the previous worksheet. Learning from his first class experience, Joshua tried a different approach in his second lesson - a group activity. This group activity was his first experience with this type of activity. Since Joshua was nervous that his students would never be able to focus their attention on what they should be doing while they worked in groups, he took some precautionary steps. One of the actions was to arrange the groups so that each group was composed of a high-level student, a mid-level student, and a low-level student. Joshua also prepared a specific worksheet involving the use of the calculators for this class, using the Cell Phone Problem. One of the problems in the activity was the following:

Sally Savvy wants to purchase a cell phone, but isn’t sure what company will offer the best deal. Sally has talked with two companies that have the following cell phone plans:

- **Company A**: 55¢ per call and $25 monthly service charge
- **Company B**: 25¢ per call and a $55 monthly service charge

1. What is the best plan to choose?
2. Under what circumstances is this choice the best option?
3. Would the other option ever be better?

All the problems required the students to use graphing calculator for the solution. The students then worked in their groups to solve the problems and compared their solutions. Several groups worked acceptably, but others still engaged in no
communications among the group members. One group just watched one of the members do all the problems without helping or asking. This group had the impression that as long as the group finished the problems they were okay. This misunderstanding might have been caused by the non-existence of individual task requirements for each member in the groups. Joshua’s directions for the group activity were too general; he only indicated that they were to solve the problem in the worksheet. With no clear description of the roles of each member of the groups, the student did not consider that they needed to work together in order to compare and share the solutions to find the best solution of the plan. When several groups determined the solutions for problems, Joshua asked them to share their solution in front of the class while a few groups continued to struggle with the problems. After sharing the solution of the problems from different groups, Joshua closed the class with several issues, identifying important steps or procedures that the students needed to be more careful when solving similar problems. The class went more smoothly and effectively than the first one as Joshua reflected, “I was pleased with the effect the grouping had on my lower level students.”

His third technology lesson was mainly a continuation of solving real-world problems related to solving the systems of two linear equations using calculators. The students worked on real-world story problems focusing on expressing the story problems into mathematical expression or equations and then finding the solutions. One example of the problems was:

Bryce and his sister Julia each have a savings account for college. In April, Bryce’s account had a balance of $2000 and he plans to deposit an additional $50 per month. At the same time, Julia’s account had a balance
of $1600 and she plans to deposit $100 per month. Predict when Bryce and Julia will have the same amount in their college accounts.

Several students had a difficult time solving this problem. The problem seemed to be straightforward requiring the students to express the story in a mathematical system of two linear equations, and then solve the system using the graphing calculator by identifying the intersection of the two lines using the graph. In general three difficulties were identified at the end of this technology lesson:

First of all, his students had difficulty in expressing the real world problems in the function form of “y = …x”: Almost half of the class had problems changing the equations into the “y = …x” form. This step was needed for the students to enter the equations into the calculators. This concept was an essential understanding in order to use the calculators to solve the problems. A basic understanding of the concept of functions was needed to see how the calculator generated the solution and the graph of linear equations.

Secondly, students’ perception on interpreting the graphs of systems of linear equation: Students only knew how to find the solution by identifying the intersection of two linear equations; they failed to interpret the correct meaning of an intersection point. Students easily responded that the solution was the point (x, y), yet the problem asked for the solution in the terms of the units of the problem.

The third one was that the calculator was seen as an additional burden that hindered student understanding of the concepts with systems of linear equations. Students had a lot of trouble dealing with the calculator, such as the graph not appearing on the screen, selecting the wrong graph, and receiving an error because of an incorrect procedure. These problems tended to deter students from using the
calculator in learning mathematics. On the other hand, if the students had been taught to explore the calculator capabilities, identifying for themselves how it worked, they might have been more interested in exploring the system of linear equation with calculator.

The result of Joshua’s class problems was shown clearly during the quiz. The quiz was about graphing and using substitution for solving systems of linear equations. The quiz consisted of three parts: solving systems of linear equations by graphing; problem solving; and solving systems of linear equation by substitution. As soon as he handed out the quiz about half of the students did not know what to do, signaling their questions by raising their hands for help. Joshua probed them to identify what they needed to solve for $y$ to get the equations into the slope-intercept form. Despite the clues and hints, they still did not know what to do with the problems. However, Joshua did not help now because it was quiz time. The students finally finished their quizzes after much struggle and frustration. Students then moved to computer lab activity to finish their computer-assisted algebra test using the school’s mathematics software.

The quiz results in Joshua’s class were low with an average of 56 out of 100. Joshua was frustrated about this fact. Even though he felt that he did his best to help the students, he also realized several shortcomings that he had during the technology lesson. He felt that the lack of an overhead projector for showing the students how to use the calculator to solve the problems had created some of the problems. Also, he had not identified a strategy for the students to use when they
encountered some problems either related to the worksheet or the calculator; thus, the class seemed to be in chaos while working on the worksheet.

In regard of the roles of several components in the program, Joshua at the beginning said that all the course works were important with each course had its own role. Nevertheless, later in the interviews he then described that the most helpful and applicable course for him was the Technology and Pedagogy course. He mentioned one example that he recalled when one of the instructors demonstrated in the classroom:

I remember one day “Ellen” (pseudonyms of an instructor) had us all stumped because she gave us these manipulative to use. She asked us to expand it beyond the physical nature of the sequence. A lot of us even though we knew, we could keep going. So we wanted to put constraints on it to avoid students’ misconception…the exposure of different ways of teaching a lesson, whether you incorporate technology and manipulative, deductive, inductive, all those I think are the most helpful.

Regarding the role of cooperating teachers, since he had two cooperating teachers, they were very helpful giving the input about the lessons coming up that they have taught it and feedback about the lesson that I just covered today and some ways maybe I can change it, help them out for tomorrow teaching. He reported that the conversation with his cooperating teachers was done on daily basis. In contrary, he did not have any informal contact with his university supervisor to consult his teaching experience other than few formal observations. The hardest part of the component in the program was the work sample. He understood the important of documenting the student exhibits and teaching experiences in the form of work sample for the university and state requirement, however the time and effort given
was so overwhelming for him. He criticized the work sample assignment as the following:

I just think it is more of a headache and a hassle but the school does need some kind of record of your performance in the classroom since they can’t be out here everyday. That’s the way they get their documentation so that’s kind of a necessary aspect of the program. ..But as a student teacher it definitely makes life a lot harder.

Despite of his strong technology background prior to entering the program, Joshua still learned a lot from the technology courses provided in the program as he responded:

I have learned a lot of different little tricks of how to use the technology which I think will be a big help in a lot of time. I have learned a lot of the different capabilities that I didn’t know before with all three of the technologies (calculator, spreadsheet and geometer’ sketchpad). And so it’s made my understanding of technology and its capabilities broadened that which will allow me to use technology in a bunch of different ways now and in the future…

Overall, he recognized the important of sequence of the technology courses in the program as meaningful, inspiring, and motivating factor to help him to learn to teach with technology.

**Summary of Joshua’s TPCK**

Joshua was confident with his ability and skills in using different kinds of technologies. This confidence was supported by his extensive experience with multiple technologies, including calculators, spreadsheets, *Geometer’s Sketchpad*, and other multimedia presentation software. In terms of knowledge and experience of teaching and learning, he took several teaching-related courses in addition to his experience in tutoring mathematics for middle and high school students and other
coaching activities. His undergraduate major in Mathematics served him well while he was tutoring and attending the preservice teacher program in mathematics.

Joshua’s overarching conceptions about the use of technology in teaching mathematics was clear in all aspects of his coursework and student teaching. In his interviews and reflections of his teaching, Joshua clearly stated his perception about the role of technology in mathematics classroom. At the beginning of his sequence of the technology lessons he stated:

The focus of this technology unit was not to have the use of the technology to be the main focus. The entire time the lesson was driven by the concept of solving systems of linear equations through the graphing method.

He also added during the interview that he used the calculator technology, as a tool only. He insisted that the technology should not shift the focus of the lesson from helping the students understand the content.

The way I teach with technology, I use it as a teaching aide. I try and get the students to use the calculator as a tool to check to see if they are doing it right instead of just relying on it to get them the right answer all the time.

He showed this understanding of his overarching conceptions of teaching mathematics with technology as he intended for his lessons.

Joshua prepared his technology lesson prior to the student teaching period. He completed all the supporting documents for the technology lessons such as the worksheets, quizzes, teacher’s notes, and list of materials needed for the lesson. His lesson plans were well developed including the National Council of Teachers of Mathematics (NCTM) standards, National Educational Technology Standards (NETS) for students, step–by-step instructional strategies from the opening to the closure of the lessons. However, Joshua’s detailed instructional strategies in the
lesson plan did not seem in line with the reasoning that went with the instruction. The detailed instructional strategies focused the students on certain steps in solving system of linear equations with calculator; yet, these actions were not well described during the lesson. One example happened when the researcher asked Joshua whether the students could identify which lines in the screen on the calculator represented a certain given equations was; he responded:

Um, they probably don’t know which equation goes with which line but if they thought about it they could figure it out but all they were worried about was finding the intersection points so they just made sure the flashing sign was on the right line and got the points.

The calculator was seen by the students as a tool that told them the answer to the problem without having to know how the graph was created in the calculator.

Joshua’s knowledge of students’ understanding, thinking, and learning with technology was challenged every day during his student teaching. He expressed his problem with classroom management many times in his reflections on teaching and in his interviews. He had a good relationship with his students while he was struggling to control them. He felt a significant responsibility for helping his students to be successful. He was concerned much of the time about getting the students to understand the concepts being taught; however, his limited experience with a large classroom of students interfered with his ability to establish a healthy classroom experience. Another possibility that Joshua technology lesson was unsuccessful due to his limited questioning skills where he failed to engage all the students in whole class discussions and discussions in their group work. His questions tended to be low level and directed at those who could answer the questions rather than encouraging all the students to think about the questions.
Even though he made several attempts to engage students with the technologies in the classroom, such as selecting the members for the group activity and developing real-world problems that related to the students’ experiences, the general structure of the lessons was to give the students clear directions to identify the method for getting from one point to the next point.

Joshua’s knowledge of curriculum and curriculum materials was determined by the structure of the lesson and supporting materials along with the objectives of the lesson and the levels of the students. Joshua’s curriculum was well-structured in a technology sequence, addressing the multiple levels of students’ understanding and the scope of the materials being covered by the standards, NCTM and NETS. In addition to his well-planned and structured documents, his less successful practice of TPCK depended on his understanding the context of curriculum in general and the specific detail of the subtopics in the unit. Joshua did not address specific details for the prerequisite knowledge and skills that needed to be addressed before actually bringing the new topic up in the class. Once when he first introduced using the calculator to solve the system of linear equations, he chose different problems to divert the students’ focus from the use of calculator to the new problems, problems that were newer that working with the calculator. One of the problems involved a system that contained a linear and a quadratic equation. The students were unaware that the intersection of the two equations resulted in two intersection points and that they needed to choose the answer that made the most sense for the problem.
Kelly

Kelly’s TPCK background

Kelly graduated with a Bachelor’s degree in Mathematics from the same university as the graduate teacher preparation program with the emphasis on secondary teaching option. Having completed several courses related to teaching in her undergraduate program, she had a strong background preparation for teaching. She had several months of informal teaching including a three-month mathematics teaching experience abroad. She took several courses related to teaching prior to the Summer term of the teacher preparation program so that she did not have to take courses in the program during the Summer term; instead she used her time in preparing her Fall term part time student teaching experience. She also completed two field practica (one at the middle school level and one at the high school level) as some of her undergraduate electives, SED 309 and SED 409. Her personal educational philosophy about teaching focused on how the role of a teacher and students’ expectations from mathematics classes intertwined and functioned as a synchronized case where they worked in partnership toward educational excellence. She believed that students needed to take responsibility for their education. For her, this perspective meant that students should be given a choice in the material that they are learning to help them find the relevance and importance of the information being taught and make connections with their own life experiences. She felt that teachers also needed to continue to educate themselves and model the importance of being a lifelong learner. This belief meant that teachers needed to stay informed about how students think and learn in order to best meet the ever-changing needs of
individual students. As a future teacher of mathematics, she strongly believed that she personally worked towards making a difference in the lives of the students, while continuing to build upon the education that she had worked so hard to acquire.

Kelly had taken two computer-related courses, Introduction to C Programming, and Social and Ethical Issues in Computer Science, from the Computer Science Department in her undergraduate program. In response to the questionnaire regarding proficiency with technology skills, at the beginning of the program, she indicated that she had proficiency with word processing for preparing her classroom work, the Internet for searching information related to mathematics, and online resources to support her mathematics courses. She also had proficiencies with several other technologies such as spreadsheets, multimedia and presentation software, concept mapping software, and graphing software. She reported that she was somewhat proficient with real time data collection, web design, and video multimedia. Her proficiencies with these technologies resulted primarily from the technology course (SED 412, Technology Foundations for Teaching Mathematics and Science) that she took during her undergraduate program before formally entering the program in the summer.

**Kelly’s TPCK during the coursework**

Kelly’s Fall term part time student teaching at the high school level was an inspiring experience for her. Kelly’s class was placed in a small high school in a rural farm community comprised of only nine classrooms and 11 teachers to teach
all the subjects, including English, social studies, government, computers, special education, science, Spanish and mathematics. The mathematics department at this high school consisted of only one mathematics teacher (her cooperating teacher).

She taught the Algebra I class that focused on learning how to graph linear equations in the rectangular coordinate plane, worked with different forms of linear equations and the concepts that corresponded to those equations (i.e. slope, intercept), and extended this work to knowledge about functions. In this student teaching, Kelly had a chance to use calculators with the motion detectors to explore different slopes. The objective for the lesson was to help the students understand the concept of slope to identify the type of equation associated with the graph of a particular equation (e.g. direct variation, horizontal, vertical lines).

She contemplated her own development of pedagogical content knowledge (PCK) during this period with the following response:

The great thing about student teaching is when I was given the opportunity to teach a given subject to two different classes. In this case I can take the time (though it is usually very brief) in between the two classes to reflect upon how the instruction and student understanding was and how I could change things for the next course. … Through this experience, I increased my pedagogical content knowledge of how to teach the surface area of rectangular prisms.

The example that Kelly gave was when she taught the students about surface area of rectangular prisms. With one class she just gave the class the method for calculating the area. Then they breezed through the rest of the activity and she had to scramble to find things to occupy their time before the bell rang. So for the next class, she set up the problem with the students and then allowed them time to problem solve and identify their own way of calculating the area. This
change was more challenging for the students and helped them to gain a better understanding of the concept.

In terms of technology use during part time student teaching, one of the lessons in Kelly’s class had the students work on an activity of graphing their walking movement versus the distance traveled using the LabPro probeware with a motion detector device; she borrowed this equipment from the teacher preparation department. At the beginning of the class, as usual after collecting the homework, she gave the students an overview of the mathematical definition of slope, including the formula for calculating the slope between two points and also some real-life connections to the idea of slope. Then, she moved quickly to a brief demonstration of how the motion detectors worked in addition to the instructions using a step-by-step description on the worksheet that the students had for the activity. The students worked in pairs of two in each group. Even though the students were in pairs, she did not really have enough space in the classroom for 10 different groups. So she selected the two most responsible groups and instructed them to work in the hallway. She kept watching the students to make sure that each student had an opportunity to walk in front of the motion detector. Sometimes she offered a suggestion or hint to help the students make progress; but, for the most part the students were able to effectively explore the ideas with the motion detectors, thus completing the worksheets.

The time for this activity seemed to be hurried in order to more quickly give the group work and the worksheet expectations. Kelly was worried about completing the activity in time so that the students could return the LabPros and
motion detectors to their storage place and clean up the classroom. So, she gave the students two warnings, one at five minutes and one at two minutes before the end of the activity; as she did this she checked each of the boxes as the students returned them to her to make sure everything was in its correction location. At the end of the class she was able to introduce the homework assignment and ask for feedback from the students about how they liked the activity.

After the class, Kelly reported that the class was eight minutes shorter than normal because of group meetings schedule at this time in the school day. In general she reported in her reflection that her students were very excited about using the new technology and even asked if they would get to use them again sometime. She was encouraged by that response. She planned to do the activity again with another class and felt comfortable with how the students responded to using the calculator technologies.

While also in her part time student teaching, Kelly designed a lesson plan that integrated technology in teaching mathematics for her campus-based instructional pedagogy with technology class (SED 574). Kelly taught her microteaching lesson on the concept of basic statistics: mean, mode, and median. At the beginning of the lesson, the introduction of mean, mode, and median were explained, then the students were asked to stand in order of their height from shortest to highest. She asked the class to identify the location of the median, first and third quartiles, and mode. She followed by asking where the median would be if several new people of specific heights joined the group; for example, if the tallest person were a basketball player joining the group, the students were to discuss how
the median shifted. Her peer student teachers enthusiastically participated during
the activity and completed some worksheet problems where they were to use the
calculator to find the solutions. Kelly demonstrated the use of the calculator to
solve one problem then requested that the class continue with the other problems.
Kelly’s use of the technology in this lesson was as a tool for solving the problems
emanating from the concept that was previously discussed.

At the end of Fall term, her responses to the questionnaire about her skills
and knowledge of various NETS Teacher standards indicated proficiency in five of
the standards: Technology Operations and Concepts, Planning and Designing
Learning Environments and Experiences, Teaching, Learning, and Curriculum,
Productivity and Professional Practice, and Social, Ethical, Legal, and Human
Issues (ISTE, 2002). However, she, like the majority of the other preservice
teachers, was reluctant to consider herself proficient in the Assessment and
Evaluation standard when using technology, specifically with the use of technology
to assess student learning and the use of multiple assessment methods for
identifying student’s proficiency with technology.

During Winter term, Kelly was actively engaged in the program classes,
completing all assignments promptly in excellent fashion. She designed several
short technology integration lessons as part of the assignment using different
technologies such as calculators, spreadsheets, and Geometer’s Sketchpad. Her
electronic portfolio included a thorough description of her work in the program,
providing several technology exhibits, samples of technology lesson plans, resource
cards, and reflections on each technology that she experienced. As part of the
course, she completed her Winter term microteaching lesson using graphing
calculators to analyze the scatter plots to visualize the relationship between the two
variables. She began the lesson by asking students (her peers) to compare the
number of pizza restaurants versus the number of U.S. representatives in a state.
After they had provided the estimates, she provided her peers with a handout with
the data about the number of pizza restaurants and U.S. representative and
instructed them to enter their data into the calculators in order to produce a graph
representing the data. Afterwards, the students discussed the relationship of the two
data sets. When entering the data, several students asked Kelly why all the states
discussed in the introduction of the class were not listed on the data set.
Apparently, Kelly had not recognized that the data set only had 40 states instead of
50. In her reflection on the lesson, she admitted to two issues that needed to be
changed.

…there are a couple of things which I would change for future teaching. I
would be sure to have all of the data already entered into my calculator.
This way, once the students finish entering their data and they answer the
questions (from the worksheet), I can be ready to show the data on the
overhead. This gives the students the opportunity to check to make sure that
they entered the data correctly. Also, I would make sure that I had a good
follow-up activity for the students to help solidify the concept of
relationships between variables using scatter plots.

Overall, Kelly felt well-prepared for her microteaching lesson and she was excited
to use the lesson again in the future since it had worked well.
Kelly’s TPCK during student teaching

The Spring fulltime student teaching was an exciting experience for Kelly. She was enthusiastic about teaching the class, having a set of well-prepared lesson plans, both with and without technology, students’ documents, worksheet and quizzes, teacher documents, supporting materials, homework policy, assessments, and additional resources. Twice a week during Winter term before actual student teaching, she attended the classes where she planned to teach for Spring term. These experiences helped her to plan her lessons and other teaching materials with her cooperating teacher. She also stated that in some instances she substituted for her cooperating teacher during her classroom visits during Winter term. The textbook that was used in her Spring term classes was a new textbook (Connected Mathematics). Kelly indicated that she was looking forward to working with the new textbook, the reform-based textbook, because it provided her with a much different approach than the traditional text she had used during her part time student teaching.

The Spring term fulltime student teaching required Kelly to have full classroom responsibility for half of the cooperating teacher’s teaching load. In terms of teaching, her lesson plans were required to be consistently planned in advance for at least five instructional hours ahead of teaching classes. While the requirement for the second work sample was to encompass a minimum of 12 – 16 instructional hours spread over at least two weeks, Kelly included 16 instructional hours with a day for catch up and review and a day for the unit exam at the end of the unit. Kelly’s technology lessons were integrated into her work sample.
Therefore, the 19 instructional lessons were intertwined between technology and non technology lessons. Observations of her technology lessons were completed at different times in the unit (a pre-technology lesson, technology lesson, and post-technology lesson) in order to see the consistency of the class circumstances both with and without technology. The technology lessons were taught on the 2nd, 4th, and 8th day of the work sample. For example, before teaching every technology lesson Kelly introduced the topic related to the concept that would be explored on the technology lesson the day before using hands-on activity. Before exploring and discussing the idea of theoretical probability and experimental probability, the students were engaged in the activity, called “What’s in the bucket?” before they actually explored the concept with the probability simulator application with the calculator.

In the first technology lesson, Kelly used the calculator to introduce the idea of .5 or 50% chance probability using an activity of flipping a coin. She used the activity because she wanted to relate the activity with a common experience of the students, such as a football game where at the beginning of the game the coin was used to determine which team received a chance to kick the ball first.

The day before the activity, she asked the students to complete a pre-assessment quiz on the introduction of probability. The pre-assessment quiz was not part of the students’ grades; however students who completed the quiz did receive extra credit points. The purpose of the pre-assessment was to see what the students already knew about the topics covered in this unit. She also planned to compare their pre-assessment with their progress during the unit to gauge their
accomplishments. After the students finished the pre-assessment, they went to the library to check out the new student workbook, called *What Do You Expect?*, and returned their other workbook. After returning to the classroom, the students were given several vocabulary terms for the unit, such as *counting tree, expected value*, *long-term average*, and *equally likely*. The students were encouraged to use the new workbook to find all of the vocabulary terms; if they were unable to find the vocabulary terms in the workbook, they were allowed to use different resources, such as other textbooks or a mathematics dictionary for help. At the end the class, she concluded with a question-and-answer period around the probability example events, such as tossing coin, rolling dice, and selecting a marble. Those students who did not finish their workbook vocabulary list were assigned homework to complete the list.

The students already had previous knowledge appropriate for studying probability before exploring the probability simulation using the TI-83 calculator. At the beginning of the first technology class, she reviewed the vocabulary terms that were to be used in the activity and had been previously discussed in class. The class moved onto an introduction of the activity, a football game event. In this event, the first possession of the ball was determined by a coin toss. So, students were asked to imagine if they were the one who was supposed to call the toss when the coin is in the air, how would they decide what to choose - heads or tails? Students discussed their choices of the coin and explained their reasons in about five minutes. The students were motivated by the story and seemed to be very engaged. The next eight minutes was used by Kelly in demonstrating several steps
for operating the probability simulator application, including turning on the calculator, finding the APPS key to identify the probability application, opening the *Probability Simulator*, running the simulator, turning off the calculator. The students attentively followed the step-by-step demonstration without having the calculators in their hands. After Kelly finished the demonstration, she distributed the calculators and worksheets with the help of several students. She let the students explore the calculator for few minutes before she explained how they would finish the worksheet activity. She explained why she did not distribute the calculators before she demonstrated using the calculator:

> My thought is to explain everything that I want to do then give them the calculators so that they can have a chance to play with it then after I let them play with it I bring them back and say, “Okay this is what I want you to do…” If I explain everything after I give them the calculator then they will not pay attention because the first thing they are going to do is play with it. So I have to give them time to play and experiment and see what the thing does and everything and after they are done with that then I can pull them back and say here is what I want you to do and they will stay more focused on the task at hand at that point then just punching buttons and seeing what it does.

While the students were doing their worksheet in groups of four or five, Kelly went around the class to check their work and answer questions. The six groups in the class were seated at round tables. The students needed to submit the finish worksheet to be corrected in the following class session. They finished working with the worksheet after about 20 minutes as she planned in her lesson plan. She actually started collecting the calculators from several students who finished their worksheet earlier. There was no discussion at the end of the activity; instead students were asked about the role of the calculator in doing the activity. The
general responses from the students were positive, indicating that the calculator helped them to calculate faster, easier, and more accurately. However, Kelly did not talk about the concept behind the use of the probability simulator. At the end she distributed another assignment related to the activity to be finished before the next lesson.

The second technology lesson was about the use of the same application, *Probability Simulator*, but with a different selection of the graph from a different activity. The activity was called “What’s in the bucket? The general outline of this activity was that the teacher had a bucket that had different amounts of different kinds of blocks in it. The goal was to figure out, without looking in the bucket, how many of each color of blocks were in the bucket. In the previous class, they simulated this activity using hands-on materials and completing a worksheet. This technology lesson was to simulate the situation from the activity to the graphing calculators.

Kelly planned to start the class by asking the students if they had any questions from the previous lesson and worksheet that the students had completed and reminded them the basic concept of previous lesson. However, the time period of the class was shortened on that day, to 26 minutes instead of 45 minutes, due to a student leader conference activity. Kelly looked frustrated since she already planned the lesson for a normal class period. So, she cut the time for the class opener by several minutes in order to finish the whole lesson. After a brief introduction to the lesson, she engaged them with the calculators and worksheets. The worksheet activity was planned for 20 minutes but was shortened to about 11
minutes. She put up the instructions of how to start the *Probability Simulator* on the overhead projector to remind the students step-by-step to get to the application, choose the type of simulation which was to select the *marbles* option, the number of marbles in the simulation, the different type of marbles, and the indication to replace the number of marbles are every drawing from the bucket. The students were assigned to pick 300 marbles from a bag and draw the graph on their worksheet. The students seemed to easily follow the directions on the worksheet. Asked about this matter, she responded that she created this activity so that the students could walk through the process, step by step. The worksheet was fairly clear and the students seemed to understand what they were to do, however the activity gave the students too much freedom and choice. The good thing with Kelly’s class was that while the students were doing their work, the cooperating teacher assisted in answering questions from the students. Considering the cooperating teacher did not have much experience working with the probability simulator, she did the best that she could in answering the questions. The closing discussion was short with Kelly asking a couple questions to check the students’ understanding about the experimental and theoretical probability related to the activity. On her reflection, she was very pleased what she had accomplished during the two technology lessons by stating:

> Despite all of the chaos which has seemed to accompany these past couple of days with shortened periods, I have been surprised and pleased with how well the students have been responding and working in class. I have completed two lessons with the graphing calculators and both have gone well. The students are treating the calculators with respect and they have been really excited about the opportunities to get to use new things in the classroom. This has helped to raise my confidence level about integrating different kinds of technology into the classroom.
She also realized at the end of the lesson the importance of sharing the technology lesson plan with the cooperating teacher before the day of the lesson. She said that she planned to show her cooperating teacher how the calculator application selected for the lesson work so that in case she needed her help, the cooperating teacher was better prepared for explaining and helping the students with the questions, especially when the time was short and a lot of students had questions at the same time.

Kelly’s third technology lesson focused on the use of one of the features of probability simulator, the Roll Dice option. The students were engaged in the two calculator simulation activities previously (the Coin Tossing and What’s in the Bucket). For this lesson, Kelly’s activity was directed to the calculator without a hands-on activity of rolling the dice. When she was asked why the lesson did not use the real materials for the activity, she commented in the interview and her reflection that there were two reasons. The first reason was that Kelly thought the students were quite familiar with the concept of rolling the dice. The students had previously played rolling dice games. The second reason was that Kelly wanted to take advantage of the calculator capability so that the students were more appreciative of the technology being used, noting that it saved them time in finishing the worksheet. In order to keep the objectives of the lesson flowing as she expected, Kelly designed a specific worksheet for the use of the Rolling Dice activity. The overall idea of the activity was that the students conducted a
simulation game of rolling the dice 250 times. The rules of the game were as follows:

- First, decide who is going to be Player A and who is going to be Player B.
- For each roll, Player A scores 1 point if the sum of the two dice is odd and Player B scores 1 point if the sum of the two dice is even.
- The person with the most points after 250 rolls is the winner. (Student Worksheet on the Rolling Dice activity)

The class began with a lesson opener on problems related to the previous lesson, the spinner activity and the coin tossing. The students were enthusiastic about learning more with the calculator. As soon as she finished with her lesson opener (about seven minutes), she distributed the worksheet and calculator to the students so that they could start the activity. Once the students finished with the simulation, they needed to draw the resulting bar graph on their worksheet. She also reminded the students to put a scale on their graph for the y-axis. The worksheet was well-structured and easy to follow by the students. However, she encountered an incident where one of the students was completely off task. She had noticed since the beginning of the class that one of her students was not doing much work. She asked him to return to the task; however the student talked back to her. When this incident happened, the cooperating teacher decided to remove him from the class. The incident was crucial for Kelly as a student teacher. She responded the incident as follows:

This situation helps me to think about how I deal with (or would deal with) students who are refusing to follow directions or who are being disruptive
in class. For this specific case, had I just let him sit there with his head down on the desk, most likely he would have not caused any problems during the lesson, though he also wouldn’t have done any work. However, since this has been an ongoing issue with this student, it seemed best to remove him from the situation.

However, she still recognized the conflicting battle in her mind between removing him from the class and what the student learned from the decision made by the cooperating teacher. Her knowledge of student learning and her responsibility for knowledge transfer were shown in her reflection:

I don’t like to allow students to just not pay attention during class because it gives the entire class the feeling that it is not important to pay attention. However I also don’t like to just send students out of class because then they are even less likely to get their work done and/or learn the important concepts of that lesson.

In general the class went well. This result was demonstrated with the students’ excitement about using the graphing calculators because the technology was something new and different. The students were also generally engaged throughout the lesson. However, many of the students spent most of the class period finishing the worksheet until Kelly stopped them for the closure of the lesson.

At the end of the technology sequence, Kelly gave a quiz on the day 9th of her work sample. The test contained six questions related to the topic of probability, three problems involved the use of the probability simulator application and three non-technology problems. Kelly gave the class some opener problems for about six minutes then moved to the quiz and distributed the calculators. She commented that she had a nervous feeling that all of the students would not get it completed. She was worried about determining how long it would take the students
to complete a certain task. She encouraged the students to first complete the problem that required them to use the graphing calculator and then move on to the other problems. During the quiz, she circulated the class answering answers that arose from different students. Every time she felt that the majority of the students were confused, she called for the students’ attention and then she explained to the whole class in order to clarify the problem. Once the class neared the end, the noise level increased and she kept giving the sign for the students to make sure that the classroom remained somewhat quiet so all had a chance to finish. However, one student did not complete the test in the allotted time, so she made an arrangement for that student to come in later that day to complete the quiz. The students who finished early turned in their spiral notebooks before they left the class. She was satisfied with what the students did on the quiz because the majority of the students completed the problems and did well. In the quiz, she included one question about how she taught the lesson using calculator specifically the probability simulator one. Kelly wrote the question on the board on how well she taught them to use the calculator, asking them to give her a grade and explain why they gave the grade that they did. The students used the other side of the quiz and give Kelly a grade, A through F, and their explanations. Most of them they gave her an A or an A- or a B+. The students thought she had explained well. One student gave a C score to her because she did not let him talk enough or let him sit by his friends. His reason was not based on the calculator. The majority the students gave her high grades because they said they learned something new by using the calculators to explore and solve probability problems.
Kelly was very much prepared before she went to her student teaching experience. She knew exactly what, when, and how she was going to teach for her student teaching. She mentioned many times the name of her cooperating teacher and university supervisor due to her close relationship with them. She appreciate and admire her cooperating teacher for helping her designed and carried out the lesson as she said in interview:

“…a cooperating teacher is like your life line. They are the ones that can say I’ve taught this before let me tell you how it goes. They are the ones that can say you are doing too much or this is what you should focus on. And ultimately I think that’s their role because I’m here for three months and then they get their classroom back. It’s their students and it’s their job and so I need to make sure I do what they need to have done. They can say hey you needed to touch on this because the students really need to know this on the state tests or they really need to know this before they go to next class…”

The next person she recognized a lot was her university supervisor. Her university supervisor suggested her different ways to incorporating technology into work sample. Her university supervisor also provided ways of improving her teaching. In addition to that, she also said in interviews:

“..my supervisors also very encouraging. When she comes out here, she always got to the things that I can work on and things that I’m doing well. It’s helpful after you teach. So you need to have somebody who is not with you everyday to say hey I just saw you do that, that’s really good, you are doing a good job. It looks like the kids are really responding well to you or wow that was a great lesson. So it’s helpful to have that outside stimulus to just kind of make you feel like okay. I’m not thanking this whole thing that I’m actually getting somewhere.

In term of technology courses, Kelly also provided a positive responds about the contribution of the technology instructor in helping her to develop sequence of technology lesson plans during winter term. Planning a head of time was very
helpful for her, even though on the real teaching usually she had to make adjustment. Regardless of her feeling of pain and tiring to design a long format lesson plan, Kelly gave an insight though about the wisdom behind designing the technology lesson plan as the following:

It has forced me to think through that process of teaching. So I think designing lesson plans ahead of time was helpful.

In another interview she elaborated what it meant for her to design a technology lesson plan:

...there are so many things that you need to think about when you sit down before you write and teach a lesson… I mean ultimately you have to think about what is it that I want my students to get out of this lesson that has to drive how you write the lesson. You have to think about what important things do I want to touch along the way. What kinds of things do I want to make sure that they understand as we go along? How am I going to get there? What kinds of examples do you use? Fortunately the book that the students are using is well designed. It’s designed almost lesson by lesson so that has been really helpful in planning the lesson.

Similar to Joshua responds, all technology courses were helpful in helping her to develop her TPCK and practices in real teaching. She mentioned several courses in the program that did not directly applicable in teaching but it helped her understood the behavior of her students during the teaching. She was grateful that technology courses in general helped her to be more confidence in teaching with technology as she stated:

I think definitely the classes have helped set it up so we can be successful when we are integrating technology. And I feel much more comfortable now than I would of on fall term even though I used some technology. I feel much more comfortable now than I did then, just having seen it having practiced with it, having used it now and felling good about where I’ve started and where I’ve come. It’s a big bonus especially now, going out and looking for a job you can say oh, I know how to use technology.
She recognized that all the courses were integrated in a way that all helpful in one way or another to make her more prepare in teaching with technology and in her career.

**Summary of Kelly’s case**

Kelly’s background in technology use was stronger than the average of students in college. She took several courses from computer science. Even though the courses were not directly related to the technology being used in teaching of mathematics in her classroom, the background of the technology courses gave her strong self-confidence in taking technology courses during the program and supported her perspective on the importance of technology. With the support of her strong background knowledge and experience of teaching (taking several teaching related courses and teaching mathematics abroad), her view about using technology in teaching was clear and strong. With respect to calculators, she started using them in the eighth grade. She grew up using calculators and used them for solving different mathematical problems but did not have a real clear idea how to teach mathematical concepts with calculators until she attended the program.

Kelly had a strong understanding of overarching conception of what it meant to teach mathematics with technology. This evidence was demonstrated in three different forms: the technology lesson plan, student teaching behaviors, and her reflections on the work sample. She mentioned that the role of technology in her classroom was very engaging. Apparently, the students began to grasp the main reason for using the *Probability Simulator* to simulate events a large number
of times more easily. Kelly used the calculator to explore the content by taking advantage of the technology capabilities to generate simulations of tossing coins, spinning wheels, and picking marbles in terms of larger numbers of items and events. The purpose of using the technology was clearly mentioned in Kelly’s technology lesson plans:

The purpose of this lesson is to get the students to start thinking about probability in terms of chance. This lesson also extends the students’ previous knowledge about simulating situations using the probability simulator application on graphing calculators.

Kelly developed her lessons during the term prior to student teaching. She consulted with her cooperating teacher about her lesson plans for using the application of probability simulator. Thus, she received much input before she finalized her technology lesson plans. Additionally, she had multiple opportunities to practice her technology lesson during the Winter term technology course. During student teaching, she kept the focus of the technology lessons on exploring the calculator features for generating and simulating experiments related to probability topics.

Her knowledge of instructional strategies and representations for teaching mathematics with technology was also visible in multiple ways: the written evidence of the lesson plans, her reflections on the work sample, and the observable behaviors during student teaching. She described her methods of transforming the technology in teaching mathematics in lesson plans through a sequence of technology lessons starting from simple mathematical concepts with calculator use into more advanced mathematical concepts with calculator applications. She related
all technology uses in the classroom with real-world applications and hands-on materials activity. At an introduction of her teaching with technology, she gave the students free time to explore the calculator after her demonstration about the related features in the calculator. Also, she gave follow up problems to the students at the end of the use of the calculator work that related to actual examples in the daily lives. During the student teaching, she demonstrated an activity of tossing the coin in front of the class and then moved the activity into technology environment where she used the calculator to generate the simulation. This strategy provided a clear identification that she tried to connect the technology concepts with the explorations with the concept of probability into technology use of probability simulator through a hands-on activity.

In terms of her knowledge of student thinking, she numerously mentioned that the students had to be given free time to explore the calculator before giving them the worksheet that involved using the calculator. When she was asked why she did that, she responded that:

My thought is to explain everything that I want to do and then give them the calculators so that they can have a chance to play with it. Then after I let them play with it, I will bring them back saying, “Okay this is what I want you to do.” If I explain everything about the worksheet and how to use the calculator at the beginning, then they will forget what to do because the first thing they are going to do is play with it. So, I have to give them time to play and experiment and see what does and everything

On a different occasion, she also mentioned the different student learning styles in middle school and high school. She stated that:

You just have to realize in middle school you just have to give them more steps, you have to go step by step by step where in high school you can
usually give them the big picture and they can fill in the rest. Middle school kids I think just need more guidance to help them through with everything.

When considering different students’ understanding, how they think and learn of mathematical concept also varies, Kelly decided that teaching the whole class meant teaching the average students with extra work for the advanced students and great assistance for the slower students. Kelly not only considered the students’ prior knowledge before every lesson, but she also connected the activity to the world with which the students were familiar.

She selected different activities to engage students’ interests about the importance of the calculator in mathematics. She integrated her technology lessons into her work sample. She organized the technology lessons mostly in the middle of her work sample unlike in Mira’s case where Mira taught the technology sequence the first week of her student teaching, at the beginning of the term. The textbook, worksheets, and different materials were selected to support Kelly’s technology sequence so that the activities were more attractive and challenging. She assessed the students’ skills in using the probability simulator with the probability concepts at the end of the technology lessons. The technology lessons were placed in an appropriate unit. She arranged the technology session in between activity and non-technology lessons so that the students felt that the technology was part of the unit rather than an add-on activity with nothing to do with the topic in the unit. She also used several supported materials from the textbook and modified worksheets from different sources to make her technology lessons more aligned with the rest of the lessons, non-technology lessons.
Similarities in Understanding in the Preservice Students’ TPCK

Mira, Joshua, and Kelly had several commonalities concerning their understanding of TPCK and teaching mathematics with technology. Those similarities included the following:

- technology was a tool to help them teaching mathematics;
- teaching with technology was not equal to teaching about technology;
- using graphing calculators helped students visualize problems graphically;
- students understood mathematics differently in their developmental phases and from their individual perspectives; and
- technology could be used in almost all topics in mathematics but the degree of use varied.

As the user of various kinds of technology while learning mathematics in their undergraduate and learning to teach mathematics in teacher preparation program, all three preservice teachers realized that technology itself did not mean much in understanding mathematical concepts unless the students themselves tried to make connections about how the technology helped them understand the concepts. Joshua mentioned on several occasions that he used the technology just an aide or tool to help the students to solve mathematics in different ways.

Similarly, Mira looked at technology as an alternative for ways of showing the students how to approach the problem using different methods. Kelly realized that technology was a tool for her students to look at the concepts from a different
perspective. Mira and Joshua, however, did not see the technology as an integral part of the mathematics classroom. Technology for them still was seen as an add-on; the students needed to know and learn the mathematical concepts without the technology, and when using the technology, the emphasis was not to include the reasoning behind the use of the technology.

Through their peer teaching and student teaching experiences, they realized that teaching with the technology was totally different from teaching about the technology. During the technology courses, they were constantly reminded of the importance of designing technology lesson plans that were not centered on teaching about the technology. Their focus was to be on designing the objectives and detailed instructional strategies in their lesson in ways that generated a clear awareness that the purpose of the lesson was not teaching mathematics with the technology. They all emphasized the mathematical content in their technology lesson plan objectives. Even during the peer teaching and student teaching experiences, the mathematical concepts were clearly shown at the opening of the lesson as well as in the closure. More evidence about their understanding that teaching mathematics with technology was not easy was provided during the interviews and their reflections on work samples. For instance, in her reflection, Mira mentioned the importance of having the topics clearly identified during the lesson: “I think that’s very important. It helps with the students so they can not be confused about what the topics are.”

The preservice teachers understood and valued the importance of giving the students multiple representations for thinking about and gaining understanding
about particular mathematical concepts. NCTM’s (2000) Representation Standard was a standard that was continually emphasized throughout the coursework in the program. This understanding was also shown on their lesson plans and the activities they designed during the student teaching. Mira and Joshua both used the activity of solving system of linear equation not only using an algebraic representation, but also solving the problem using graphing calculators. Similarly, Kelly, in her probability lesson, used the graphing calculator bar charts and table features to demonstrate the results of tossing a coin. They also clearly stated in their technology lesson plans the support of the NCTM standards in recommending the use of multiple representations in teaching mathematics; they often quoted NCTM’s statement as a reminder that “instructional programs from pre-kindergarten through grade 12 should enable all students to- create and use representations to organize, record, and communicate mathematical ideas” (NCTM, 2000). This common understanding was specifically emphasized as they used the calculator to help students visualize the mathematical concepts and problems graphically.

Student thinking has rarely been a focus of preservice teachers because of their focus on their own performance and teaching. However, with the involvement of the technology, the preservice teachers acknowledged the students’ processes in learning with and about the technology in the mathematics classroom. This thought was due to their experience in the program in learning with and about the technology throughout the coursework. Preservice teachers contemplated students’ thinking to some degree every time they taught mathematics with technology. Part
of that contemplation was that preservice teachers always took into consideration their students’ prior knowledge in mathematics and technology along with how they were thinking with the technology used in the classroom. The effect of their considerations about the students’ thinking was that the preservice teachers designed careful activities for the students to be engaged in during the lessons - student worksheets, and various assessments of the students’ knowledge about the mathematics when using the technology. Kelly stated in her reflection the importance of understanding students’ different ways of understandings: “I am learning that most of these situations have to be handled on a case-by-case basis and what’s best for the individual student as well as the class as a whole must be taken into consideration.” She also indicated:

I think that at this age level that is what works the best. But I look at it now at the whole unit …and more of using the technology would be awesome because the kids really enjoy it and they seem really engaged in the activity and the topic and just staying focused on what they are supposed to be doing.

**Differences in Understanding in the Preservice Students’ of TPCK**

In addition to these similarities, the preservice students demonstrated several differences that were reflected in their particular levels of TPCK development. Their understandings about the levels of student involvement with technology were different. This understanding determined how they arranged the use of the technology into different parts of the lesson (beginning, middle, or end of the unit). This understanding also influenced their specific instructional strategies incorporated in a lesson that included technology. This understanding affected the types of technology used and how those technologies were used in the instruction –
as a demonstration tool, for completing a worksheet, or involvement in a project related to mathematics and technology. Preservice teachers who viewed technology as an add-on tool that students needed to learn in addition to the mathematical concepts were more likely to either use the technology to show what features in the technology were useful for doing the same actions they did with paper and pencil or demonstrate how to solve the problem with certain features of technology. If the preservice teachers’ perception about technology increased to the level of including the technology tool for exploring the existing problem in a more dynamic, comprehensive, and challenging manner, then these preservice teachers designed worksheets to guide the students to explore the different capabilities of the technology for extending the problem into more meaningful concepts and broadening the problem. Advanced preservice teachers assigned projects related to the technology and mathematical content discussed in the class.

The second difference was in the preservice teachers’ perception about the efficacy of the technology use. While they recognized that technology was a tool available for the mathematics classroom that offered significant assistance in helping students’ understanding of mathematics, they were different in their perceptions when judging how much the technology role should play in the classroom learning. Joshua believed that technology was best used as a tool to verify solutions of the problems completed previously using paper and pencil. For him, the role of technology was limited. Even though Joshua had a strong background of using different technologies, he was not convinced that technology provided more than just a verification tool. Mira saw technology as an aid to help
students solve more complex problems. However, she still held a strong belief that those students needed to be taught with paper and pencil before using the technology. On the other hand, Kelly strongly believed that technology could be used for more than a verification tool at the end of the unit. She was confident that appropriately-used technology could serve as a tool to build mathematical concepts and could be an integral part of the mathematics curriculum to aid students in developing a better understanding.

This belief difference influenced the preservice teachers’ determination of the amount of technology in the lesson. The stronger the preservice teachers’ beliefs were that technology offered multiple advantages in the teaching and learning, the longer and consistently they considered using technology in their plans. This belief affected the levels of student involvement with technology in their lessons. If the preservice teachers were not convinced that students learned more with technology, their demonstrations of the use of technology in teaching mathematics were more limited. Meanwhile, if the preservice teachers had stronger beliefs that the technology had more potential in improving students’ understanding of mathematical concepts, the technology was used to do class group activities or individual project assignments where the students were allowed to explore ideas with the technology.

The third difference was in how they valued the importance of exploring technology in the mathematics classroom. This belief influenced how they determined a specific instructional strategy for delivering a lesson with technology. Their approaches were varied - deductive, inductive, or emphasizing procedural or
conceptual knowledge. When the preservice teachers did not value the importance of exploring with technology, they tended to use a deductive approach that emphasized memorizing procedural steps to solve the problems. On the other hand, when the preservice teachers strongly valued the importance of exploring mathematics with the technology, they used a more inductive approach that focused on a more conceptual understanding. In this approach, the preservice teacher, Kelly, also gave students a chance to find ways that were easier for them to understand the mathematical concepts needed for approaching the problems.

In addition to their different levels of TPCK, several factors also influenced how they implemented their pre-planned technology lessons during student teaching, such as the availability of technology at school, the grade level of the students, and the unit being taught. Those influential factors and the technology atmosphere resulted in different practices among three preservice teachers while they were teaching with technology. Mira faced the problem of the availability of technology at the school when she planned to use the calculator on three consecutive days as she taught her sequence of technology lessons. Since her school did not have a set of TI-83 plus calculators to use by all the students in her classroom, the teacher preparation program loaned the calculators for her classroom use. Joshua, on the other hand, did not have the calculator-availability problem but he did not have the projector to display the calculator into the screen. Lack of this display unit created chaos in his class. The students could not follow the steps that Joshua tried to explain. He had to check each student’s calculator screen in order to make sure they were all at the same place in the lesson; his inability to demonstrate
to all the students at once resulted in a time consuming process where he
individually helped the students and several students became impatient and restless.
When several students tried to go ahead in solving the problem with the calculator
without following Joshua’s instructions, they received error messages on their
screens. Those errors then caused the students to raise their hands asking help to
Joshua. Chaos erupted when Joshua was helping one of the students and the rest of
the class did not know what they needed to do to continue with the problem.

Kelly’s case provided an interesting successful story of teaching with
technology. She was successful in her classroom when she taught probability in her 8th
grade class. Kelly implemented her pre-planned technology sequence lesson using the
worksheets, assessment plan, and additional resources she had prepared during the
previous term. Her rationale of intertwining the technology lessons and non-
technology lessons in designing the scope and sequence of the work sample resulted in
a good way to avoid the conflict of technology availability. She scheduled the
calculators in advance with her university supervisor. The only problem that Kelly
faced was the conflict with the school’s scheduling. The school sometimes changed
the class period for several reasons, such as changing to announce a school award.
When Kelly was asked how she planned the lesson and prepared the class, she noted
that the key issue was that:

You had to really go through into every detail that you are going to do in your
classroom. It’s not just the matter of putting words in the lesson plans, but it is
more of contemplating the class before you teach in your mind so that you feel
that you were in a real class with your students.

Her class saw the technology as a tool to help them gain a better understanding of
theoretical and experimental probability, a lesson that was modeled in their technology
methods coursework. This view influenced how Kelly designed her assessment problem. On her assessment, she was not only assessing the mathematics concepts by themselves, but also how the students learned the concepts using the calculator as learning tool.

The summary of the preservice teachers’ TPCK development can be described into two different sections: (1) their development of their TPCK and how that development was reflected in their practices of TPCK in teaching with technology; and, (2) what components in the program helped these preservice teachers develop and practice their TPCK. Preservice teachers’ development of four TPCK components were confirmed through three different sources of data, the classroom artifacts (such as technology lesson plan, worksheet, and quizzes), the behaviors of teaching with technology during the student teaching, and the reflection of their teaching reported in their work sample. By triangulating the three data sources, the study attempted to develop the patterns or commonalities in their development and practices of TPCK. Their different TPCK levels definitely affected how they relied on their TPCK in practice teaching. Several examples were given in the summary of each case on how Mira, Joshua, and Kelly developed the rationale of their lessons, prepared their lesson, and implemented their lesson in the real classroom.

The roles of several components in the program (coursework, microteaching, work sample, instructors, university supervisors, and cooperating teachers) were acknowledged and recognized by the three preservice teachers. The coursework was the main component in the program these preservice teachers relied on before their actual teaching. The roles of instructor were less visible due to their integral nature of
the courses. However, all of the preservice teachers recalled how their instructors modeled the use of technology in class and were inspired to integrate technology into more meaningful ways. Despite the advantages of the peer teaching in the microteaching session for providing a space for sharing ideas for incorporating technology in their lessons, these preservice teachers still felt the situation was unrealistic since their students in the classroom were their peers.

The role of the university supervisor was viewed as helpful by some but less helpful by others. This influence depended on their relationship with the university supervisor beyond the formal expectations for both. Similarly, the role of the cooperating teachers was perceived differently by the preservice teachers. Building a pleasant relationship with the cooperating teachers was an important aspect that influenced the preservice teachers’ behaviors and performances in the classroom. Kelly and Joshua cases were different from Mira’s; Mira did not really have a close relationship with her cooperating teacher. These relationships were viewed as particularly important when preservice teachers taught their work sample. One noticeable example of the affect of this relationship was the curriculum sharing the Kelly engaged in with her cooperating teacher. In her interview, she pointed out that her cooperating teacher gave her the curriculum and discussed with her which content and topics she would be teaching and when she would be teaching them. Another example in Kelly’s classroom was when her cooperating teacher helped her to answer several students’ questions to assist when many students raised their hands at the same time in a group activity. Similarly, Joshua’s relationship with his cooperating teacher was helpful for him in designing his lesson plan ahead of time even without consulting
with his university supervisor. He talked to his cooperating teacher on a daily basis to
design and evaluate his teaching. Contrarily, Mira did not have a close working
relationship with her cooperating teacher. She had designed her technology lesson
plans during Winter term, but these plans were not what she exactly taught during the
student teaching. Fortunately, she was able to modify her actual technology lessons
during the first week of Spring term before she taught her technology lessons.
CHAPTER V
DISCUSSION

Introduction

The main purpose of this study was to investigate secondary mathematics preservice teachers’ development of their technology pedagogical content knowledge (TPCK) in a subject-specific teacher preparation program that integrated technology throughout the program. The study also led to the enlightenment on a question on how an integrated model supports preservice teachers’ use of their TPCK in their practices in teaching mathematics with technology. The mathematics preservice teachers’ similarities and differences in their levels of development of TPCK were certainly associated with their practices of teaching mathematics with technology during their student teaching.

This chapter presents and discusses a model generated from the similarities and differences among the three preservice teachers with respect to their development and implementation practices of TPCK during the coursework and student teaching. The model provides the teacher preparation program a clearer idea of different categories of preservice teachers’ level of TPCK practices in teaching mathematics with technology. The discussion includes a consideration of the role of several influential components of the program in the TPCK development. Limitations, implications and recommendation of future research related to the development of preservice teachers’ TPCK in mathematics teaching are each described in the conclusion of this chapter.
The topic of preservice teachers’ development of TPCK has been part of the current areas of interest with respect to integrating technology and teacher education and has been studied in recent years by some researchers. This study was aimed at providing teacher preparation programs a better understanding of the facts of preservice teachers’ development of their growing understandings and practices during an instructional program that integrated technology throughout the multiple facets of the program. A better understanding of the development process of the preservice teachers served as pre-assessment information in order to determine which certain treatments were the most effective and efficient in preparing them with the knowledge and skills needed for teaching mathematics with technology. The knowledge and skills about technology that preservice teachers needed to learn was shown in the written assignments in the forms of their technology lesson plans, students’ documents, teachers’ documents, worksheets, quizzes and work samples; equally important, the experiences in practice teaching of mathematics with technology during the preservice teachers’ student teaching was essential in their preparation.

With respect to the emerging status of this field of research, Niess’ study (2005) pioneered the investigation on the development of science and mathematics preservice teachers’ TPCK during a one-year teacher preparation program that integrated technology throughout the program. The major contribution of Niess’ study was to establish a framework outlining the idea of TPCK in teaching mathematics and science with technology. This study relied on the four
components framing the description of the development of TPCK in a teacher preparation program (Niess, 2005), stating specifically that teachers need:

1. an overarching conception of what it means to teach mathematics with technology;

2. knowledge of instructional strategies and representation for teaching mathematics with technology;

3. knowledge of students’ understanding, thinking, and learning with technology in mathematics;

4. knowledge of curriculum and curriculum materials that integrate technology with learning mathematics.

Given the broad nature of the four components, this study provided the reality of preservice teachers’ understanding of TPCK during the program and the practicality of their practices of TPCK during student teaching that confirmed the existence and level of their TPCK. The four components of TPCK in this discussion are elaborated based on the results of this study in relationship with current research.

**Overarching Conception**

The first component of TPCK, an overarching conception of what it means to teach mathematics with technology, was reflected by the preservice teachers in three forms: their understanding of their roles in teaching mathematics with technology; their understanding of the roles of technology in teaching mathematics;
and their understanding of ideas within and outside the mathematics being taught and technology being used.

Mira’s case provided an example of how she understood her role in teaching mathematics with technology as an instructor that informed the students what they needed to know, showed them how to use the technology, and instructed them to practice with similar problems. Similarly, Joshua’s case illustrated how he viewed his task as demonstrating how to use the technology to solve the problems and then have students solve similar problems with the same technology. Even though he created a worksheet and group activity at one time, he still had a tendency to control his students’ work on the worksheets and expect that they solve the problems exactly as he did. The students were not given time to explore different possibilities for solving the problems. Additionally, the students were fearful that too little time was available for them to finish their worksheets; Joshua also felt that the time constraint was a barrier due to the massive amounts of content to be covered in the class. These two preservice teachers had the perceptions that running the class meant to execute their pre-planned technology lesson over a certain period of time. On the other hand, Kelly’s perception about her role in teaching mathematics with technology was different. She understood that her role was to guide the students to learn mathematics with the technology. Her perceptions influenced her practice during student teaching where she allowed her student to explore. Even though the time she dedicated for that exploration was limited, she was able to maintain the environment of exploration. This notion was supported in Wang’s study (2002) indicating that those teachers’ perceptions about
teaching and learning influenced their computer use in classrooms. In other words, “The way that a teacher uses computers gives an indication of her underlying pedagogical philosophy” (Becker, 2000, p. 11). Similarly, preservice teachers’ understanding about the roles of technology, teaching with technology, and learning mathematics with technology shaped their practices in teaching mathematics with technology. Wang’s study elaborated that preservice teachers did not teach differently in classrooms with computers from what they do in classrooms without computers. The comparison in Wang’s study showed no significant difference in preservice teachers’ perceptions of the teacher’s role when teaching with computers and their perceptions of the teacher’s role when teaching without computers in terms of teacher-centeredness or student-centeredness. However, when preservice teachers understand their roles in teaching mathematics with technology as an instructional designer, facilitator, and guidance, their perceptions of the classroom shifts to a more student-centered approach. Eventually, their practices in teaching with technology are more likely to be different than their teaching without technology.

In terms of understanding the ideas within and outside mathematics and technology, this study found that the three of preservice teachers demonstrated how they tried to situate the mathematics concepts into real world applications. Mira provided an example of a problem about selecting a business card from different companies while Joshua gave an activity of choosing a cell phone plan from different companies. In a similar approach, Kelly presented the activity of tossing a coin, picking up a marble, and spinning a spinner.
All of the preservice teachers attempted to link the technology with activities outside mathematics. Besides their similarities in their understanding that a connection needed to be built between mathematics and real world, however, their detailed instructional strategies and representations in the activities and the identified real world problems were dissimilar because of their different understandings of their roles in the activity. Preservice teachers’ understanding and practices are influenced by numerous personal factors, including their personality and belief systems. In order for instructional technology to be successfully implemented, preservice teacher beliefs about technology and their values with respect to technology need to be shaped. If this shift does not occur, the integration of instructional technology in education does not occur on a broad scale (Dexter, Anderson, & Becker, 1999).

**Instructional Strategies and Representations**

The simplified phrase “Teachers teach the way they were taught” in some ways misleads the complex nature of how preservice teachers learn to teach and how they go through the process of practicing their teaching. Even though, by nature, the preservice teachers observe and evaluate different instructional strategies from elementary through college undergraduate classes they took, their experiences do not absolutely predetermine how they would teach in the future due to the emerging nature of technologies that were unavailable when they were students. However, preservice teachers’ prior learning experiences, taking the courses during the undergraduate program that are related to topics they teach
during student teaching such as algebra and probability, impacts their teaching
during the student teaching experience. One example given by Al-cuoco (2001)
about the common practice in undergraduate course that strongly relates to how the
mathematics classroom is taught in secondary level in general is how mathematics
is perceived. In the undergraduate courses, mathematics is perceived as an
established body of knowledge that is inherited from previous generation to the
next one. At the end, the prospective mathematics teachers would not see the
theorems of geometry, the formulas of trigonometry, and the methods of algebra as
the products of doing mathematics, instead they would perceive that these artifacts
are seen as the mathematics. When preservice teachers beliefs about mathematics is
limited to as mentioned above, they would tend to teach deductively with teacher
center approach in their classrooms. Therefore, the role of teacher preparation
program that integrates technology with mathematical concepts through the use of
hands-on activities and a real world context is expected to help students to perceive
mathematics as part of the students’ life and not merely as collections of difficult
topics to learn at school.

Using a single strategy to present mathematical concepts likely does not
reflect the complexity inherent in many concepts. In contrast, repeated exposure to
information from varying perspectives helps learners establish the
interrelationships necessary to mediate deep processing and effective retrieval of
lesson concepts (Hooper & Rieber, 1995).

The transfer of mathematical content through engagement with different
instructional strategies was expressed as being valued by Joshua. He believed that
effective teachers needed to incorporate as many learning styles as possible into their instruction, including oral, visual, and hands-on learning. He felt it important that he work to reach more students by incorporating these styles, allowing the students to build a stronger understanding of the material being studied.

During student teaching, Joshua implemented his expressed beliefs about using various instructional strategies. On the second day of his technology lessons, he changed his demonstration approach to a group activity that allowed the students to work collectively in solving the problems. Even though he continued to struggle to get his students to follow the instructions on the worksheet properly during the lesson, he did try to use different methods to make his point. In his second technology lesson, he realized that the lack of the overhead projector resulted in the increase in the noise level in the classroom. Joshua’s case suggested that when technology use is new in the classroom, the students need to be actively engaged with the new technology, in order to become familiar with the tool and using the tool as a learning tool; but this active involvement typically results in a higher noise level.

A similar case was found in the Apple Classroom of Tomorrow (ACOT) project. They identified that active participation usually took place in collaborative learning projects, producing “noise” that was contrary to a traditional learning environment in the classroom (Sandholtz, Ringstaff, & Dwyer, 1997). This change in the environment troubled the preservice teachers at the end of the lesson due their lack of understanding about the nature of a technology lesson.
Another issue that affected Joshua’s classroom was with his questioning skills during the lesson as a means of engaging the students in the topic. A teacher’s questioning skills do affect how students think about the lesson. When preservice teachers use low-level questions during the lesson, the students are more likely to lack interest in the lesson. When preservice teachers use questions at higher levels of the taxonomy, students are encouraged to think more deeply and critically and participate into discussion.

Kelly demonstrated a transformation in her development of the second component of TPCK. Kelly selected the group activity of tossing a coin, picking up marbles from the bag, and using a spinner activity in order to represent the mathematical concept of experimental and theoretical probability. She incorporated a real world problem of choosing the first ball on the football game by tossing the coin as an analogy to the activity that the student were doing in the classroom. This strategy prepared the students for using the technology to simulate these actions.

**Students’ Understanding, Thinking, and Learning**

Clearly, the three preservice teachers in this study were all technology users with different degrees of prior involvement with technology and with the kinds of technology used. This fact in some way influenced their views on learning. As Bracey (1994) indicated, teachers who use technology are more apt to view learning as an active process and knowledge as actively constructed by students. Besides their concern for specific instructional strategies in teaching with technology, the preservice teachers demonstrated a concern for students’ learning.
How they viewed their students’ learning and thinking affected their perception on what roles they should play in the classroom. Multiple studies (Dwyer, Ringstaff, & Sandholtz, 1991; OTA, 1995) have shown that technology has the capability of putting students in active roles in the learning process where the teachers’ roles shift to those of coaches or facilitators.

Much evidence confirmed the preservice teachers’ understanding of the knowledge of students’ understanding, thinking, and learning. The first evidence was in Kelly’s technology class. On her lesson plan, she specifically dedicated time for her students to explore with the calculators by themselves after she demonstrated several features of the calculator. Another incident in Kelly’s class was evidence of her acknowledgment of students’ knowledge of technology and the active role that they took during that lesson. In that instance her students discovered a different way than Kelly had initially demonstrated in class for tossing the coin using the probability simulator application. As soon as Kelly recognized this difference, she posted it for the class to help them all understand and use the easier way. In the same class, Kelly also encountered a situation with one of her students involved with other school activities. This student was often called out to the staff office to complete her tasks as a student leader. So, when this student returned to the class from the staff office, she had obviously missed much of the class. Kelly approached that student and handed her a worksheet that the rest of the class had almost completed, and guided that student throughout the steps that needed to be done; then she told that student to ask her whenever she had problems finishing the worksheet.
The use of group work in the classroom was another way of demonstrating their concern for students’ thinking and understanding. All of the three preservice teachers dedicated specific times for their students to interact with each other in the activities. Joshua’s, Mira’s, and Kelly’s technology lessons all included group activities that used different amounts of time. In all the activities, the preservice teachers reminded the students to check with their neighbors if they had questions before asking for her help. Their interactions with the students were obviously visible in the classrooms when the students often asked any problems they faced in finishing their worksheets. This approach aligned with the recommendation by ISTE (2000) about the role of technology in creating new learning environments that focused on collaborative work, student active learning, and student-centered learning. More specifically, ISTE suggested that teachers teach students to apply strategies for solving problems with their technologies and to use appropriate tools for learning, collaborating, and communicating. The idea of learning mathematics with technology was still fresh in the mind of the preservice teachers since they also had just experienced learning with the various technologies in the program.

**Curriculum and Curriculum Materials**

Kelly’s technology sequence was strong in terms of the organization of the topics and the integration of the technology, activities, and the content that needed to be included in the curriculum. Intertwining technology with the activity was evidence of her understanding that certain curricula need to be delivered to the students and the technology used must be mutually beneficial to both the content and its use. This approach paralleled what Flick and Bell (2000) suggested, specifically that technology
instruction should develop students' understanding of the relationship between technology and science. The idea of developing relationships between mathematics and the probability simulator application was clearly demonstrated in Kelly’s classroom.

One manifestation of the preservice teachers’ understanding about the curriculum materials was expressed in Mira’s worksheet in her first technology lesson. She modified some of the problems she got from the textbook and online resources to develop an appropriate worksheet matching the level of the students and the topics discussed. She ordered the problems from simple to more complex and included some figures that represented the screen of the calculator at each step. She did not rely only on the textbook due to her adoption of a technology lesson that the textbook did not provide.

**Preservice Teachers’ Practices of TPCK during Student Teaching**

As a summary of the practices of the three preservice teachers in teaching with technology, Figure 5 was developed as a means of describing the different levels of their practices with integrating technology in teaching mathematics during student teaching. The different categories in the table were adopted and modified from the evolution of thought and practices of technology integration model by ACOT project (Sandholtz, Ringstaff, & Dwyer, 1997). The ACOT model represented mainly the level of inservice teachers use of technology beginning from a non-user stage to an innovation stage. This model looked at the inservice teacher technology integration from the perspective of the inservice teacher as well.
In this study the technology integration practices of the preservice teachers were examined through the lens of their teaching behaviors in classroom instruction. In addition, the preservice teachers levels of practices in this study were all beyond a non-user and none reached the innovation stage. The model shown in the Figure 5 was formed to identify not only the preservice teachers’ objectives, planning, and arrangement in term of the technology lesson, but also how they actually practiced their TPCK in real classroom including step-by-step instructional strategies that preservice teachers take in teaching their technology lesson.

Figure 5  Level of Preservice Teachers’ Practices of TPCK in Teaching Mathematics with Technology

<table>
<thead>
<tr>
<th>Level</th>
<th>Purpose</th>
<th>Planning</th>
<th>Arrangement</th>
<th>Instructional Activity</th>
</tr>
</thead>
</table>
| Accepting | • Complete the program. • Practice problems at the end of the unit. • Technology is not a consistent thought in thinking about teaching learning mathematics | - Independent, separate from previous lesson plan  
• No assessment plan  
• No follow up lesson  
• No specific worksheet | - No transition to the lesson or from it.  
• Lesson is added on at the end of a unit. | Teacher  
• distributes the technology  
• demonstrates the technology; Students  
• follow the teacher’s demo with technology;  
• complete a worksheet;  
• no assignment |
| Adapting  | • Attempts a different way of solving the problems. | - Adds to an existing lesson plan with technology instructions.  
• Selects problems from previous worksheets.  
• No assessment plan  
• Not integrated in a sequence of lessons | - Short transition lesson included.  
• Middle or end of a unit. | Teacher  
• demonstrates the technology.  
• distributes the worksheet and/or technology. Students  
• try technology individually;  
• work in groups to finish the worksheet;  
• assigned similar problems |
Using the model to describe the three preservice teachers, Mira, Joshua, and Kelly resulted in the following description categories. Mira and Joshua were at an *adapting* stage shown on their main objectives of trying a different way of solving the problem with technology. In addition, their lesson plans did not specifically address a different approach or instructional strategies that focused on utilizing technology to give the students a different way of learning the mathematical concepts. Besides they designed a specific assessment to determine the students’ understanding of the concepts with the technology; their lessons tended to be separate from a specific unit and were usually taught only at the end of some unit. This description described their behaviors at the *adapting* stage.

Kelly, on the other hand, was classified in the *exploring* stage. She clearly showed in her lesson that the objective of the technology lesson was to explore a different way of understanding the concept of experimental and theoretical probability

<table>
<thead>
<tr>
<th>Exploring</th>
<th>Advancing</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Demonstrates new ways of thinking about concepts with technologies besides what used in the textbook</td>
<td>• Introduces or builds a new concept in teaching math</td>
</tr>
<tr>
<td>• Additional instruction to an existing lesson plan</td>
<td>• New lesson plan.</td>
</tr>
<tr>
<td>• Chooses problems for additional worksheet</td>
<td>• Worksheet.</td>
</tr>
<tr>
<td>• Plans for assessment to specific section of the unit</td>
<td>• Different assessment format.</td>
</tr>
<tr>
<td>• Introduces concept given first</td>
<td>• Plans for following lesson.</td>
</tr>
<tr>
<td>• Short transition lesson.</td>
<td>• Prepares the sequence of the lessons for an entire unit</td>
</tr>
<tr>
<td>• Placement in middle of the unit</td>
<td>• Begins the unit.</td>
</tr>
<tr>
<td></td>
<td>• Follows up with similar activity in future lessons.</td>
</tr>
<tr>
<td>Teacher</td>
<td>Teachers</td>
</tr>
<tr>
<td>• demonstrates the technology use in the activity;</td>
<td>• scaffold the technology use in the activity.</td>
</tr>
<tr>
<td>• distributes the worksheet and/or technology.</td>
<td>• involve technology use in assessment</td>
</tr>
<tr>
<td>Students</td>
<td>• assigned technology project.</td>
</tr>
<tr>
<td>• try technology individually;</td>
<td>• Students</td>
</tr>
<tr>
<td>• use the technology to finish the activity;</td>
<td>• • work in groups to do activity;</td>
</tr>
<tr>
<td>• discuss the results in a whole class;</td>
<td>• • present their groups findings.</td>
</tr>
<tr>
<td>• assigned similar homework.</td>
<td></td>
</tr>
</tbody>
</table>
using probability simulator. She integrated the hands-on activity with technology so that the students felt the technology being used was part of the lesson not as an add-on that needed to be learned outside mathematics. She not only combined the use of technology and instructional strategies as an integral part of a whole lesson but also assessed the students’ understanding of the concept in a different way, a way that was consistent with the learning environment and context. The technology was used in different sections of the unit so that the existence of technology was not seen as outside mathematics work.

**Limitations of the Study**

This exploratory case study aimed to investigate how mathematics preservice teachers developed and practiced their TPCK in a technology integrated teacher preparation program; the study also aimed to investigate the influence of several components in the program on these preservice teachers’ development and practices of TPCK. To satisfy the three tenets of a qualitative method for describing, understanding, and explaining the description of preservice teachers’ development of TPCK, the design and method of the study chosen developed three in depth cases. Furthermore, the objectives of the study inevitably directed the study’s attainment of rich and comprehensive descriptions of the preservice teachers’ TPCK prior to the program, during the coursework, and during the student teaching. However, several limitations were noted in the study due to different facts that were unavoidable during a one year period of the study.
The study attempted to show that the analysis of the data relied on all the relevant evidence that addressed the most significant aspects of each case study and were based on the researcher's prior expertise and knowledge related to the field being studied. Despite purposefully and carefully selecting the participants, only preservice teachers from one of universities in the Northwest were selected; these cases were not intended to represent the whole population of mathematics preservice teachers nationwide. The intent of study was not to draw a generalization in this respect due to limited numbers of subjects and scope of the study. However, any generalization of the case study findings is limited to the cases themselves or similar cases.

Another limitation in the study was in the data collection process where the three preservice teachers were placed in locations that were two hours apart. Scheduling conflicts sometimes prevented the researcher from gathering observations and interviews of all three technology lessons for each of the preservice teachers. One occasion happened when gathering data from both Kelly and John. They needed to transfer to the university to attend a late afternoon seminar immediately after finishing teaching and with the driving distance, little time existed for post conference interviews; neither of these preservice teachers had time to do a post-observation interview on that day. Therefore, the post interviews were rescheduled for the next classroom observation. The post interviews for the two classroom observations were combined at the later observation. These circumstances possibly reduced the detailed, more-timely reflections and perhaps eroded the nuances of their classroom activities due to the
uniqueness of time sensitive the events. However, the field notes, observation form, and classroom artifacts of that day helped the researcher to trace the events of that day and stimulate the conversation when the post conferences were conducted.

Another limitation during the data collection also happened in Mira’s class. She did her technology sequence the first week of Spring term; therefore, the first non-technology observation was not conducted in timely manner. However, Mira’s work sample documented what she did on the first week of Spring term. The documents included the lesson plans, student worksheet, and other supporting materials.

Generally a researcher's personal beliefs and values are reflected in the choice of a research topic and interpretation of findings, particularly in qualitative research. The interest and involvement of the researcher in the program in teaching and assisting the preservice teachers during their preparation for student teaching may affect how the researcher interpreted the data. Several steps were taken to limit that effect through developing a specific interview protocol for the pre- and post-observations interviews, obtaining audio recordings of the interviews, and collecting supporting documents related to the technology lesson being taught by the preservice teachers along with other classroom artifacts. The cross-checking data analysis was developed to triangulate all the data sources to assure the reliability of the data.

Another uncontrollable limitation of the study was that all three preservice teachers used calculators as their technology tool in their technology lesson during Spring term. This phenomenon may be viewed for its advantages as well as
disadvantages. Since they all used the same technology, they were able to compare and contrast the same kind of technology rather than two or three different technologies. A second advantage was that the researcher was able to gain a deeper, more comprehensive description about the integration of this specific technology. The disadvantages of the situation was that the scope of technology being studied narrowed and did not provide a broader look at how to deal with technology in general. Due to the consistently evolving nature of technology, investigation of a broader array of technologies could have provided more benefits to teacher education and preservice teachers. However, despite the reliance on calculators during Spring term, different technologies were used during their part time student teaching in Fall term. Mira used Geometer’s Sketchpad and Kelly used the motion detector probeware technologies in their classroom activities. The descriptions of how they each dealt with those two different technologies were also described on the case study. Additionally, even though they all used calculators in their classroom, Kelly used different features on the calculator than Mira and Joshua. Kelly utilized the application software that was downloaded from the Texas Instrument website, while Joshua and Mira only used the graphing ability of the calculators.

In order to reduce the distraction of classroom management problems that preservice teachers commonly face (thus providing the opportunity to focus on how preservice teachers conducted their technology lessons) the method for selecting the participants included observations during the part time classroom experience during Fall term. These observations strongly indicated that that problem continued
to be a hindrance that detracted the preservice teachers’ efforts in teaching mathematics with technology. To offset this data collection distraction, the interviews after the technology lesson also addressed the unexpected events that happened. By asking this question, the researcher was able to obtain information about the intent of the lesson in terms of the technology used.

Rigorous and extensive methods of sampling, data collection, and data analysis provided the study with valuable and significant information to describe the intent of the investigation. Therefore, continuous development and consistent progress from the limitations of the study could improve the quality of future research. Some of these limitations also presented fruitful avenues for future research under the similar themes and topics.

**Conclusion and Implications of the Study**

Overall, the emphasis of the teacher preparation program in this study in helping preservice teachers acquire TPCK transformed the preservice teachers’ understanding described by the four components of TPCK. However, the diversity of beliefs, teaching, and technology backgrounds affected their understanding and development of TPCK throughout the program. Their understanding of the four components of TPCK were manifested into more practical terms and beliefs into different data sources such as their overarching conceptions of what it means to teach mathematics with technology was influenced by their different understandings of their roles as teachers of mathematics with technology, the roles of technology in teaching mathematics, and their ideas within and outside mathematics and technology. The roles
of the program coursework, peer teaching, work samples, and all the personnel involved in the program were significant factors in their development of TPCK. The preservice teachers also reported that the integration of technology into all the coursework in the program was intense. Each course played its own role in helping preservice teachers to develop their TPCK.

Even though the knowledge of content, pedagogy, and technology among the three preservice teachers during the coursework was developed in an integrated fashion, not all three preservice teachers were equally successful in carrying out their technology lesson plans in their teaching of mathematics with technology in actual classroom unless certain conditions supported their instruction. Different levels of preservice teachers’ practices (accepting, adapting, exploring, and advancing) were also influenced by the availability of technology, the familiarity with the content, and the student level being taught. Although the preservice teachers were given several opportunities to practice teaching their technology lessons through microteaching with their peers during the coursework, they needed additional preparation for dealing with the different aspects of the school climate, such as the school personnel and students’ behaviors.

Designing a technology lesson plan is an important skill that preservice teachers must have in preparing them to teach mathematics with technology; but there are several different factors that need to be considered in their preparation. Niess (2001) described this step as the “pre-active” stage where preservice teachers carefully planned their lesson before implementing the lesson in the classroom. However, preservice teachers need to establish good classroom management to carry out the
lesson plan successfully in addition to preparing the other materials such as
worksheets, quizzes and assessments, and other supported resources. Niess’ (2001)
study supported this finding where she found that the technology lesson needed to be
conducted when the preservice teachers were familiar with the classroom management
(such as, knowing student’s name, where the students were seated in the classroom,
and how to cluster the students in terms of their learning ability levels).

In general, all of the influential components in the program were confirmed as
being helpful in developing preservice teachers’ TPCK and supporting them in
practicing their TPCK. Each preservice teacher perceived the roles of the components
differently in many cases, but they all agreed about the important role of the sequence
of technology courses in the program. The technology courses were the main source
that helped them develop and practice their TPCK. However, they were unable to
distinguish from among those technology courses which ones were the most helpful
due to the interconnected and integrated nature of technology sequence. This finding
suggested that the sequence of the technology courses ws well-developed and
structured in accordance with the preservice teachers’ needs in helping them to be
more prepared for teaching with technology.

Despite the evidence that the technology sequence was strongly interconnected
and positively in helping the preservice teachers develop their TPCK, the preservice
teachers still understood and practiced their TPCK differently. This finding implied
two things for the program. First of all, the technology proficiency assessment at the
beginning of the program needs to be taken into consideration in designing the
technology courses so that the program is able to monitor individual progress during
the program. This information can be used to adjust the pace of the activities in the course so that all preservice teachers progress appropriately.

The second implication about this finding was that preservice teachers had very positive thoughts about taking the technology courses. Taking technology courses before going into student teaching became a necessity for the preservice teachers. This conception is a positive affect if it is continued for the incoming preservice teachers as a precaution. If they were unable to adequately complete the technology courses, their teaching with technology in student teaching is more likely a difficult task. Summing up from the two implications, the program needs to keep the structure of the course and instruction open to the progressing nature of technology in education.

**Recommendations for Future Research**

Referring to Joshua’s case when his students had difficulty in translating the real word problem solving into mathematical form, his technology lesson was in jeopardy. The situation became a quandary between continuing to use technology or dropping the technology and return to a paper and pencil lesson so that the students were able to solve the problems without calculators. Justifiably, certain ways of using technology can improve the students’ understanding of mathematical concepts. On the contrary, some other ways of technology use might hinder students’ understanding of the mathematical concepts. The recommendation for the future research is to focus on identifying determining factors that affect preservice teachers’ use of technology in mathematics classroom where the technology is intended to improve students’ understanding of mathematics. In the perspective of a teacher preparation program, the
research needs to focus on identifying the necessary steps that help preservice teachers in justifying their technology lessons as a way of improving rather than hindering students’ understanding.

The development of preservice teachers’ TPCK varied in their degree of understanding and practices. Their different understandings of TPCK affected their practices in the actual classrooms. Preservice teachers’ practices of TPCK during their student teaching fell into four different levels (accepting, adapting, exploring, and advancing) depending mainly upon their understanding and knowledge of teaching mathematics with technology – their TPCK. Recommendations for future research for the teacher preparation programs include:

- How can the teacher preparation programs improve the level of preservice teachers’ practices in teaching with technology?
- How can the teacher preparation program narrow the gap among the different levels of preservice teachers’ practices of TPCK?

This study also suggested that those preservice teachers, who had clearer objectives and better preparation in their lessons and who had a good relationship with the cooperating teacher, tended to be more successful in incorporating technology in their classroom teaching. The preservice teachers realized the importance of designing technology lessons in advance despite their recognition that changes happened during the actual teaching. Research is needed that identifies strategies for guiding preservice teachers’ in their decision-making during lessons with technology. What are the factors that influence their decisions for changing their lesson plans? How do they reflect and contemplate last minute decisions to change their lesson plans in their future teaching?
Another finding in this study suggested that cooperating teachers influenced the preservice teachers’ preparation of the lesson, their comfort in teaching, and their TPCK practices. The involvement of the cooperating teachers, their contributions, and participation before the lesson, during the lesson, and after the lesson affected the preservice teachers’ successes in their student teaching direct or indirectly. Despite their influence on preservice teachers’ practices, the cooperating teachers’ roles had little impact directly on preservice teachers’ use of technology in the classroom due to their lack of technology background. One recommendation for future study regarding this topic is: What is the relationship of cooperating teachers’ technology background and practice on the degree of technology involvement in the preservice teachers’ practices of TPCK? In broader terms future study should also investigate the relationship of the course instructors’, university supervisors’, and cooperating teachers’ understanding of TPCK and their understanding of its development in preservice teachers’ TPCK.

Realizing that the nature of technology is evolving and the uniqueness of individual preservice teachers with respect to their technology, pedagogy, and content knowledge background, the researcher understands how far this research is from the perfect study. Providing the three cases with rich descriptions of their TPCK background and their understanding and practices with specific technology, the researcher hopes that this research offers a small significant contribution to the field of research in technology use in teacher preparation program and mathematics teaching.
REFERENCES


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APPENDICES
## APPENDIX A

### Teacher Preparation Program Outline
Overview of the Initial Licensure Program in Science and Mathematics Education 2004-05

<table>
<thead>
<tr>
<th>Summer Term (11 credits)</th>
<th>Fall Term (12 credits)</th>
<th>Winter Term (16 credits)</th>
<th>Spring Term (15 credits)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>August 1 - 19</strong></td>
<td><strong>Sept 26-Oct 28</strong></td>
<td><strong>Oct 31 – Dec 2</strong></td>
<td><strong>Jan 9 –Mar 17</strong></td>
</tr>
<tr>
<td><strong>Summer Intensive Course</strong></td>
<td><strong>Part Time Student Teaching Practicum</strong></td>
<td><strong>Preparation for Work Sample 2</strong></td>
<td><strong>Full Time Student Teaching Practicum</strong></td>
</tr>
<tr>
<td>3 week intensive course preparing students for student teaching. Includes a practicum working with middle school students on campus.</td>
<td>Plan work sample I; spend 2 mornings per week at the school site; meet with cooperating teacher and supervisor weekly to prepare for November teaching; take classes at OSU in the afternoon</td>
<td>Part time student teaching 4 hours/day in mornings Monday through Friday at school site; complete work sample for first authorization level; take classes at OSU in the afternoon</td>
<td>Full-time student teaching experience, plus a weekly seminar at OSU on Thursdays from 1600 - 1900. Complete work sample for second authorization level and for primary endorsement area; if approved, may complete a second work sample for a second endorsement at the same authorization level.</td>
</tr>
<tr>
<td><strong>Fall Coursework</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Methods I (3 cr)</td>
<td>Methods II (3 cr)</td>
<td>Methods III (3 cr)</td>
<td>Analysis of Classrooms II (3 cr)</td>
</tr>
<tr>
<td>Math: SED 552</td>
<td>Math: SED 554</td>
<td>Math: SED 556</td>
<td>All: SED 515</td>
</tr>
<tr>
<td>Science: SED 553</td>
<td>Science: SED 555</td>
<td>Science: SED 557</td>
<td></td>
</tr>
<tr>
<td>Pedagogy I (2 cr)</td>
<td>Advanced Topics in Science/Math: Pedagogy (3 cr)</td>
<td>Advanced Topics in Science/Math: Pedagogy (3 cr)</td>
<td></td>
</tr>
<tr>
<td>Math: SED 574</td>
<td>Math: SED 589</td>
<td>Math: SED 589</td>
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</tr>
<tr>
<td>Science: SED 573</td>
<td>Science: SED 599</td>
<td>Science: SED 599</td>
<td></td>
</tr>
<tr>
<td>AND Technology &amp; Pedagogy I (1 cr)</td>
<td>AND Technology &amp; Pedagogy II (1 cr)</td>
<td>AND Technology &amp; Pedagogy II (1 cr)</td>
<td></td>
</tr>
<tr>
<td>All: SED 571</td>
<td>All: SED 572</td>
<td>All: SED 572</td>
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<tr>
<td>Part Time Student Teaching Practicum (3 cr)</td>
<td>Psychology of the Adolescent (3 cr)</td>
<td>Professional Internship: Full Time Student Teaching (9 cr)</td>
<td></td>
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<tr>
<td>All: SED 509</td>
<td>All: ED 512</td>
<td>All: SED 510</td>
<td></td>
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<tr>
<td>Graduate subject matter course if needed** (3 cr)</td>
<td>Graduate subject matter course if needed** (3 cr)</td>
<td>Analysis of Classrooms I (3 cr)</td>
<td>Professional Development &amp; Practicum: Completion of Initial Licensure Notebook (3 cr)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>All: SED 511</td>
<td>Math: SED 581</td>
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<td>Science: SED 592</td>
</tr>
</tbody>
</table>
APPENDIX B

Demographic Questionnaire

Aligning Preservice Teacher Knowledge, Skills and Beliefs about Technology in Teaching Mathematics to National Educational Technology Standards for Teachers (NETS-T)

Section I. Technology operations and concepts
1. I can explain the difference between software and hardware.
   Yes…. No …. Not sure....
2. I can operate both Mac and PC.
   Yes…. No …. Not sure....
3. I can explain terminology related to computer technology.
   Yes…. No …. Not sure....
4. I can demonstrate installing content-based software.
   Yes…. No …. Not sure....
5. I can demonstrate the basic features of presentation/multimedia software (i.e. PowerPoint, Inspiration, Dreamweaver, etc).
   Yes…. No …. Not sure....
6. I am confident with basic troubleshooting techniques (i.e. When the monitor does not display the computer projection, identifying that one or more of the application need to be reinstalled because of a corruption on the file, etc).
   Yes…. No …. Not sure....
7. I believe that it is important for teachers to have basic knowledge of concepts and operations of computer technology for their classrooms.
   Yes…. No …. Not sure....

Section II. Planning and designing learning environments and experiences
8. I can design lesson plans implementing technology that are developmentally appropriate and support the needs of diverse learners in mathematics.
   Yes…. No …. Not sure....
9. I can plan mathematics strategies using technology to enhance student learning.
10. I can identify and locate mathematics online resources dealing with learning activities and teaching strategies.
   Yes…. No …. Not sure....

11. I believe that it is important for mathematics teachers to know how to utilize technology-based materials to plan for their lessons.
   Yes…. No …. Not sure....

Section III. Teaching, Learning and the curriculum

12. I am aware of the content standards and student technology standards mentioned in National Council of Teachers of Mathematics (NCTM) standards and National Educational Technology Standards (NETS) for students.
   Yes…. No …. Not sure....

13. I can use technology to support student-centered activities in mathematics.
   Yes…. No …. Not sure....

14. I can develop mathematics lesson plans applying technology to enhance students’ higher order thinking skills.
   Yes…. No …. Not sure....

15. I can operate and apply content-based software to support students’ learning in mathematics.
   Yes…. No …. Not sure....

16. I believe that technology implementation in the mathematics curriculum is important for students in their learning activities.
   Yes…. No …. Not sure....

Section IV. Assessment and Evaluation

17. I can evaluate mathematics content-based software.
   Yes…. No …. Not sure....

18. I can apply technology resources in assessing students learning of subject matter knowledge.
   Yes…. No …. Not sure....

19. I can apply information collected from Internet resources to improve my teaching practice.
Yes…. No …. Not sure....

20. I can evaluate the appropriateness of students’ use of technology resources.
   Yes…. No …. Not sure....

21. I believe that it is important for teachers to apply technology resources to facilitate a variety of effective assessment and evaluation strategies.
   Yes…. No …. Not sure....

Section V. Productivity and professional practice

22. I believe that the use of productivity tools (i.e. Microsoft word, Excel, Powerpoint, Hyperstudio) will positively affect the quality of teaching practice.
   Yes…. No …. Not sure....

23. I believe that teachers should continuously be informed about new technology tools for their professional development.
   Yes…. No …. Not sure....

24. I believe that teachers should evaluate and reflect on their professional practice regarding the use of technology in support of student learning.
   Yes…. No …. Not sure....

25. I believe that the use of communication tools (i.e. email, discussion board/forum..) are important in communicating and collaborating with peers, parents and students.
   Yes…. No …. Not sure....

26. I believe that my competent use of technology will increase my chances to get hired.
   Yes…. No …. Not sure....
Demographic Information

1. Gender
   Female.... Male....

2. Age
   A. Under 22
   B. 22-29
   C. 30-40
   D. Above 40

3. What is your major for your highest level of education?
   a. Mathematics
   b. Engineering
   c. Science
   e. Other (specify __________________________)

4. Please list the undergraduate courses taken in mathematics (from Mathematics Department)

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<tr>
<th>Course number</th>
<th>Title of the course</th>
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</table>
5. Please list the undergraduate courses taken in teaching or related courses in teaching

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<th>Course number</th>
<th>Title of the course</th>
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6. Please list the undergraduate courses taken in computer technology or related to computer technology

<table>
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<th>Course number</th>
<th>Title of the course</th>
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</table>

7. Please indicate your formal teaching experience.
   
   a. None
b. Less than 3 months  
c. 3 — 6 months  
d. 6 — 12 months  
e. 1 — 2 years  
f. Other (specify ___________________________)

8. Please indicate your informal teaching experience.  
   a. None  
   b. Less than 3 months  
   c. 3 — 6 months  
   d. 6 — 12 months  
   e. 1 — 2 years  
   f. Other (specify ___________________________)

9. Please indicate the licensure you are currently seeking (check all that apply)  

<table>
<thead>
<tr>
<th>Grade</th>
</tr>
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<tbody>
<tr>
<td>3-5</td>
</tr>
<tr>
<td>5-8</td>
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<tr>
<td>8-12</td>
</tr>
</tbody>
</table>

10. Hour(s) of computer usage at home or outside school (in a week)  
   a. none  
   b. 1-2 hours  
   c. 2-5 hours  
   d. more than 5 hours  

11. Hour(s) of computer usage at school (in a week)  
   a. none  
   b. 1-2 hours  
   c. 2-5 hours  
   d. more than 5 hours
APPENDIX C

Technology Proficiency Questionnaire

How Technology Proficient are you?

Place indicate with “X” in the space that best describes your personal proficiency at helping students to utilize the particular technology to achieve desired learning outcomes within an instructional setting.

<table>
<thead>
<tr>
<th>Technology or Instructional Strategy for science/math content areas:</th>
<th>Proficient for Teaching</th>
<th>Proficient for Self-use only</th>
<th>Somewhat Proficient</th>
<th>Not Very Proficient</th>
<th>No Experience with This Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Student use of basic computer operating systems and file management</td>
<td></td>
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<tr>
<td>2. Student use of word processing software</td>
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<tr>
<td>3. Student creation and/or use of spreadsheets</td>
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<tr>
<td>4. Student use of graphing software</td>
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<tr>
<td>5. Student use of information search strategies for the Internet</td>
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<tr>
<td>6. Student use of Internet sources to download text, graphics, and data</td>
<td></td>
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<tr>
<td>7. Student use of multimedia (Power Point, video, still images, etc.) for presentations and/or documentation</td>
<td></td>
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<tr>
<td>8. Student use of email and email attachments for communication with experts, peers, and others for help, etc.</td>
<td></td>
<td></td>
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<tr>
<td>9. Student use of technologies that provide for real-time data collection</td>
<td></td>
<td></td>
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<tr>
<td>10. Student ability to do webpage design and to use authoring software</td>
<td></td>
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<tr>
<td>11. Student use of conceptual mapping software (e.g. Inspiration)</td>
<td></td>
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</tr>
<tr>
<td>12. Student use of science/math content specific software and Web sites</td>
<td></td>
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<tr>
<td>13. Student use of video digitizing and movie editing technology</td>
<td></td>
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<tr>
<td>14. Student use of graphing and programmable calculators</td>
<td></td>
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<tr>
<td>15. Other*</td>
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</tbody>
</table>

* Optional: use this bottom line to include another technology skill or proficiency that you feel would be useful in your teaching and the students’ learning of math or science concepts.
APPENDIX D

Open-ended Questionnaire

Please identify the role of the six components on the first column by stating the evidence or the reasons on the associated cell in relation with their role in providing you with the knowledge of technology, subject matter, and teaching and learning.

Thank you for your participation.

<table>
<thead>
<tr>
<th>Component</th>
<th>Technology</th>
<th>Subject Matter</th>
<th>Teaching and Learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Courses</td>
<td>Support/ Evidence</td>
<td>Support/ Evidence</td>
<td>Support/ Evidence</td>
</tr>
<tr>
<td>E-portfolio/ Worksample</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microteaching/Peer Teaching</td>
<td></td>
<td></td>
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<tr>
<td>Faculty</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>University Supervisor</td>
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<td></td>
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<tr>
<td>Cooperating Teacher</td>
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</table>
APPENDIX E

Preservice Teacher Interview Protocol before Observation
Pre-Classroom Observation Interview Protocol
(Used prior to first class observation, shorter for next observation)

Preliminary
What is the name/title of this course?
What class period was this or (anything related to the time constrains)?
Can I have a copy of the instructional materials you used for this lesson?

A. Learning Goals
1. I’d like to know a bit more about the students in this class.
   Tell me about the grade levels and general ability levels of students in this class.
2. Please help me understand where this lesson fits in the sequence of the unit you are
   working on. What have the students experienced prior to today’s lesson?
3. What is the specific purpose of today’s lesson?
4. What do you think the students will gain from today’s lesson?
5. What is the next step for this class in this unit?

B. Content/Topic
6. What led you to select and teach the mathematics topics or concepts in this lesson?
   Is it included in any curriculum standards?
   Is it included in an assigned textbook or program designated for this class?
   How important was that in your decision to teach this topic?

C. Resources Used to Design the Lesson
7. What resources did you use to plan this lesson?
   (Textbook title, internet, journal, other sources)
8. Were these resources/materials/activities designated for this class/course or did you
   choose to use them yourself?
9. What do you like about these resources/materials/activities?
10. Did you plan this lesson essentially as it was organized in [name of resource/material]
    or did you modify it in important ways?

D. The Teacher
11. How do you feel about teaching this topic?
    Do you enjoy it? Why?
    How well prepared do you feel to guide student learning of this “content”?
    What course(s) or activities have you taken to learn about this particular content area?
    (Probe for courses in the program)
    How helpful were they?

12. How comfortable do you feel using the “instructional strategies” involved in
    teaching this lesson?
What course(s) or activities have you taken in the science and mathematics education (SMED) program to learn using these strategies? (Probe for courses in the program) How helpful were they?

13. Have you taught this lesson before?  
   *If yes:* How different was today from how you have taught it previously?  
   Is there anything about this particular group of students that led you to plan this lesson this way?

**E. Context**

14. Sometimes schools and districts make it easier for teachers to teach science/mathematics well, and sometimes they get in the way.
What about your teaching situation influenced your planning of this lesson?  
Probes:  
   Did the facilities and available equipment and supplies have any influence on your choice of this lesson or how you taught it?  
   Were there any problems in getting the materials you needed for this lesson?

15. Sometimes other people in the university and school can influence your planning of a lesson. Did your supervisor teacher or cooperating teacher have any influence on your choice of this lesson and/or how you taught it?

**Note:**

16. When the student teacher uses technology, additional question will be asked on section D. (The Teacher)  
   Why do you select this specific technology for your lesson?  
   How comfortable do you feel using the “technology” involved in teaching this lesson?  
   What course(s) or activities have you taken in the science and mathematics education (SMED) program to learn using this technology? (Probe for courses in the program)  
   How helpful were they?

Thank you for your time.
APPENDIX F

Preservice Teacher Interview Protocol after Observation

Post Interview Protocol
(Obtained at the end of each observation)

1. Was your plan adequate for your teaching?

2. Had you planned adequate time for the different parts of your lesson?

3. What worked well and what needs improvement?

4. Were you well prepared? (Students hands-on materials, technology, worksheet, etc)

5. Did you have to improvise because you did not have all the materials you needed?

6. What would you do differently?

7. What came up unexpectedly that you had not planned?

8. How do you feel you handled that unexpected event?

9. How did the students respond to your lesson in general? (as you thought they would or differently)

10. Could you identify what each student learned in this lesson?

11. Did you engage all the students or were only a few of them actively engaged?
APPENDIX G

INFORMED CONSENT DOCUMENT

Project Title: Secondary Mathematics Preservice Teachers’ Development of Technology Pedagogical Content Knowledge in Technology Integrated Throughout the Program Model

Principal Investigator: Dr. Margaret L. Niess
Research Staff: Gogot Suharwoto

PURPOSE

This is a research study. The purpose of this study is to investigate the following two questions: How do the mathematics preservice teachers construct or develop their TPCK in a subject-specific teacher preparation program that integrates technology throughout the program? What features or components in the program are related to the development of preservice teachers’ TPCK? The purpose of this consent form is to give you the information you will need to help you decide whether to be in the study or not. Please read the form carefully. You may ask any questions about the research, what you will be asked to do, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear. When all of your questions have been answered, you can decide if you want to be in this study or not. This process is called “informed consent”. You will be given a copy of this form for your records.

We are inviting you to participate in this research study because you are part of the teacher preparation program that integrates technology throughout the course in secondary preservice mathematics teacher program.

PROCEDURES

If you agree to participate, your involvement will last for a term, spring term 2005. The following procedures are involved in this study. At the beginning of fulltime student teaching during spring term, 4th week of March 2005, you will be contacted by email through the mailing list in the program regarding the request to participate in the study. Participant Informed Consent document will be distributed to you if you are willing to participate in the study. The form will be distributed when you come to the department to take one last course in the program that meet once a week. The questionnaire will be mailed you if you do not present at the first week of the term. You will have a one week period to consider, respond, and sign the form. After signing the Participation Inform Consent form, the questionnaire will be distributed to you if you agree to participate at 1st week of April 2005. From the questionnaire, the selection of the three participants will be decided at the second week of April 2005. When you are identified as the participant of the study, the university supervisor and cooperating teacher will be contacted through e-mail regarding your involvement in the study. During this contact the researcher will describe a brief description about the study which focuses only to you as preservice teacher. Meeting to three participants will be set up at the third week of the spring term to discus about the detail of scheduling for interviews and class observations. The discussion will concentrate on topics you plan to teach with the technology during the student teaching, scheduling the visit on the day of teaching, and any important information about rule and regulation of visiting your school site. The class observation will be conducted for five times on your classroom, one pre technology lesson, three technology lessons, and one post technology lesson. The pre and post-observation interview will be done in the classroom
before and after the class session. The specific time will be arranged to the class to make sure that there is enough time before or after the class session to do the interviews that last about 15-30 minutes for pre-observation and 5-10 minutes pots observation. Pre-observation interview, classroom session, and post-observation will be audio recorded. The pre-observation and post-observation interview protocol will be used on each lesson to all participants. While observing the class the researcher will take notes and sit in the back of the class.

**RISKS**

There are no foreseeable risks to participating in this study.

**BENEFITS**

The potential personal benefit that may occur as a result of your participation in this study is keep track on the progress you are doing in the practicum teaching. The researchers anticipate that the teacher preparation program may benefit from this study by examining their program and taking the necessary step to improve the quality of the program.

**CONFIDENTIALITY**

Records of participation in this research project will be kept confidential to the extent permitted by law. However, federal government regulatory agencies and the Oregon State University Institutional Review Board (a committee that reviews and approves research studies involving human subjects) may inspect and copy records pertaining to this research. It is possible that these records could contain information that personally identifies you. In the event of any report or publication from this study, your identity will not be disclosed. Results will be reported in a summarized manner in such a way that you cannot be identified.

**AUDIO RECORDING**

By initialing in the space provided, you verify that you have been informed that audio recordings will be generated during the course of this study. The audio recording will be collected in two occasions, during the interview before and after teaching and during the teaching where the researcher will use a small device to be attached to the preservice teacher. The audio recording will be intended to capture the general lecture and conversation that happen in the classroom with focus on the preservice teacher. The audio data will be transcribed by the researcher into text using pseudonyms as the identification of participants. The data reporting will also uses pseudonyms as well. Only researcher and major professor will have access to the real names. At the end of the study, the recorded tape will be erased.

_____________ Participant’s initials

**VOLUNTARY PARTICIPATION**

Taking part in this research study is voluntary. You may choose not to take part at all. If you agree to participate in this study, you may stop participating at any time. If you decide not to take part, or if you stop participating at any time, your decision will not affect your grade or any form of assessment in the program.
QUESTIONS

Questions are encouraged. If you have any questions about this research project, please contact: Dr. Maggie L. Niess, 541-737-1818, (niessm@onid.orst.edu) or Gogot Suwarwoto, 541-737-9829, (suwarwog@onid.orst.edu) If you have questions about your rights as a participant, please contact the Oregon State University Institutional Review Board (IRB) Human Protections Administrator, at (541) 737-3437 or by e-mail at IRB@oregonstate.edu.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Participant's Name (printed):

____________________________________________________

_______________________________________   ___________________

(Signature of Participant)     (Date)

RESEARCHER STATEMENT

I have discussed the above points with the participant or, where appropriate, with the participant’s legally authorized representative, using a translator when necessary. It is my opinion that the participant understands the risks, benefits, and procedures involved with participation in this research study.

_______________________________________   ___________________

(Researcher Signature)     (Date)