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

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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. Multiple data sources were used to obtain information toward answering the research questions. Overall, the emphasis of the teacher preparation program in this study in helping preservice teachers to acquire TPCK transformed the preservice teachers' understanding described by the four components of TPCK. However, the diversity of beliefs, teaching, and technology background affected their understanding and development of TPCK throughout the program.

Key Words : TPCK, Preservice mathematics teachers, Subject specific, Teacher preparation program, Understanding, Beliefs.

I. Introduction

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. 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

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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).

The emphasis on integrating technology in preservice teacher programs has thus become an essential element in teacher education program topics today. In general, teacher preparation programs have adopted three different models: 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, research strongly suggested that the stand-alone information technology courses are generally not an efficient way to help new teachers use technology in schools (e.g., 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. 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 teacher shave more opportunities to learn by designing and practicing how to teach their subject matter with technology.

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).

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.

II. Review of Literature

1. Technology

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 (NationalCouncilofTeachersofMathematics[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.

2. Technology Pedagogical Content Knowledge (TPCK)

The phrase of Technology Pedagogical Content Knowledge (TPCK) was originally derived from the idea of Pedagogical Content Knowledge (PCK) by Shulman (1986). 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 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).

III. Methodology

1. Participants

The researchers 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 where selected to represent the diversity of the group.

Selection of the participants began through an 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 identify the impact of various 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 student 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 participated in 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 All names are pseudonyms to provide anonymity for these participants.) 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).

2. 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 researchers 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.

3. 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 and 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 full time 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.

Questionnaire

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] (International Society for Technology

in Education, 2002). The questionnaire 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 on their proficiency with technology was used during the Summer term of the program. In addition, an open-ended questionnaire 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 Observation

The researchers 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 researchers 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 researchers were 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 researchers to become familiar with the preservice teachers, the faculty, and the university supervisors to establish a positive communication and working relationship with the researchers.

Observations of Preservice Teachers

Throughout the program, the researchers used specific observational techniques to collect data on a wide range of preservice teacher's teaching, 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 teacher's lesson plans, intended class homework, assignments, quizzes, and projects. During the observations, the researchers were 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 when the researchers needed clarification of some events prior to or after teaching. These informal interviews were not audio-recorded, but recorded in the researcher's journal. Similar short informal interviews were conducted with faculty, university supervisors, and cooperating teachers to gain additional information in describing their support of student teachers in terms of the use technology in teaching mathematics.

The participants were interviewed prior to 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 pre-teaching interviews gathered the goals, objectives, instructional approaches, and assessments planned for the lesson. The post interview 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 audio-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. 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 Researchers and Researchers' Journal

The researchers were an important part of the process in this qualitative study. The researchers' 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. The researchers were 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 researchers kept 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.

4. Data Collection

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 thatdate, 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.

5. 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?

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). 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).

IV. Results

1. Individual Case Studies

Mira's Case

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 did not only learn 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 of an average student in terms of her accomplishments in gaining 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 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 researchers, 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.

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(she?) 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's Case

Joshua was a confident student 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 course work 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 concern 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. 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 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's Case

Kelly's background in technology use was more than 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 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 term 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 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.

2. 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 peerteaching 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 course work 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 course work. 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.

3. Differences in Understanding in the Preservice Students' 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

ofthe 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 concept, 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 course work. 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 intotwo 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 (course work, microteaching, work sample, instructors, university supervisors, and cooperating teachers) were acknowledged and recognized by the three preservice teachers. The course work 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 teaches 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.

V. Discussion

1. Instructional Strategies and Representations

Using a single strategy for presenting mathematical concepts unlikely reflects the complexity inherent in many concepts. In contrast, repeated exposure to information from varying perspectives helps learners to 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 the 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 work activity to allow the student to work collectively in solving the problem. 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 ACOT (Apple Classroom of Tomorrow) project. They identified that active participation usually took place in collaborative learning projects which produced "noise" that was contrary to a proper learning environment in the traditional 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.

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.

2. Preservice Teacher's 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 view on learning. As Bracey (1994) indicated, teachers who use technology view learning as an active process and knowledge and as something students must construct rather than receive passively. Besides their concern for specific instructional strategies in teaching with technology, the preservice teachers demonstrate 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 the student in an active role in the learning process and that the teachers'roles might best shift to ones of coaches or facilitators.

Several evidences confirmed 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 what 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 let them all understand and use the easier way. In the same class, Kelly also encountered a situation with one of her students who was involved with other school activities. This student was often called out to the staff office to do her job as a student leader. So, when this student returned to the class from the staff office, obviously she 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 a specific time for their students to interact with each other in the activity. 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 center learning. More specifically, ISTE suggested that teachers teach students to apply strategies for solving problems with their technologies and to use the 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.

3. Curriculum and Curriculum Materials

Kelly's technology sequence was well done 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 the 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 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 that matched 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 from the textbook due to her adoption of technology lesson that the textbook did not provide.

4. Preservice Teachers' Practices of TPCK During Students Teaching

In summary of the different practices of the three preservice teachers in teaching with technology, Figure 1 was developed as a means of describing the different levels of preservice teachers'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 [Apple Classroom of Tomorrow] 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 were likely able to reach an 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 1] Level of preservice teachers' practices of TPCK in teaching mathematics with technology

Level	Purpose	Practice		
		Planning	**Arrangement**	**Instructional Activity**
Accep-ting	· 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
Adapt-ing	· Attempts a different way of solving the problems.	·Adds to an existing lesson plan with technology instructions.	·Short transition lesson included.	Teacher ·demonstrates the technology. ·distributes the worksheet and/ or technology.

		·Selects problems from previous worksheets. ·No assessment plan ·Not integrated in a sequence of lessons	·Middle or end of a unit.	Students ·try technology individually; ·work in groups to finish the worksheet; ·assigned similar problems
Explo-ring	· Demonstrates new ways of thinking about concepts with technologies besides what used in the textbook	·Additional instruction to an existing lesson plan ·Chooses problems for additional worksheet ·Plans for assessment to specific section of the unit	·Introduces concept given first ·Short transition lesson. ·Placement in middle of the unit	Teacher · demonstrates the technology use in the activity; · distributes the worksheet and/ or technology. Students · try technology individually; · use the technology to finish the activity; · discuss the results in a whole class · assigned similar homework.
Adva-ncing	· Introduces or builds a new concept in teaching math	·New lesson plan. ·Worksheet. ·Different assessment format. ·Plans for following lesson. ·Prepares the sequence of the lessons for an entire unit	·Begins the unit. ·Follows up with similar activity in future lessons.	Teachers · scaffold the technology use in the activity. · involve technology use in assessment · assigned technology project. Students · use the technology to finish the activity; · work in groups to do activity; · present their groups findings.

Using the model to describe the three preservice teachers, Mira, Joshua, and Kelly resulted in the following description categories. Mira and Joshua were on 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 did design

a specific assessment to assess the students'understanding of the concepts with the technology; their lessons tended to be separated from a specific unit and was usually taught only at the end of some unit. This adapting stage clearly defined the behaviors they had in common.

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 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 -that recognized the learning environment. The technology was used in different sections of the unit so that the existence of technology was not seen as outside mathematics work. Her teaching behaviors during the technology lessons in the classroom were seen in the instructional activity column as described in Figure1 at the adapting stage.

5. Conclusion and Implications of the Study

Overall, the emphasis of the teacher preparation program in this study in helping preservice teachers to acquire TPCK transformed the preservice teachers' understanding described by the four components of TPCK. However, the diversity of beliefs, teaching, and technology background affected their understanding and development of TPCK throughout the program. Their understanding of the four components of TPCK were 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 course work, peer teaching, work samples, and all the personnel involved in the program were significant to the development of preservice teachers'TPCK. The preservice teachers also reported that the integration of technology into all the course work 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 course work began to develop 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 real classroom unless certain conditions support their teaching instruction. Different levels of preservice teachers' practices (accepting, adapting, exploring, and advancing) were also influenced by the availability of technology being used and 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 course work, they still 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 they implementing the lesson in the classroom. However, preservice teachers need to create a 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 seat in the classroom, and how to cluster of 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 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 one was the most helpful due to the interconnected and integrated nature of technology sequence. This finding suggested that the sequence of the technology courses were 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 technology sequence was strongly interconnected and positively helping preservice teachers to 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 should be taken into consideration in designing the technology course so that the program would be able monitor every individual progress during the program. This information could be used also to adjust the pace of the activity of the course so that all preservice teachers could progress in appropriately manner. 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 necessary need for preservice teachers. This conception could be a positive affect if it was passed along to the incoming preservice teachers as a precaution. If they messed up with the technology courses, it would definitely make their teaching with technology in student teaching more difficult. Summing up from the two implications, the program has to keep the structure of the course and instruction open to the progressing nature of technology in education.

Looking back 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 go back to the paper and pencil lesson so that the students would able to solve the problem without calculator. It is justifiable to say that certain ways of using technology could improve the student understanding of mathematical concept. In contrary, some other ways of technology use could be a hindrance for student to understand the mathematical concept. The recommendation for the future research should be focusing on what are the determining factors that the use of technology by preservice teachers in mathematics classroom becomes an aid to improve students understanding of mathematics. In the perspective of teacher preparation program, the research should be focusing on what are the necessary steps that could help preservice teachers to be able to justify their technology lesson as an improving factor or a hindrance to the 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:

The study also suggested that preservice teacher with clearer objectives and better preparation in their lesson and who built 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 always happened during the actual teaching. Research is suggested to identify strategies for guiding preservice teachers' in decision making during the lessons with technology. What are the factors that influence their decisions for changing their lesson plans? How do they reflect and contemplate their last minute decisions in changing their lesson plans in their future teaching?

Another finding in the 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 the 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?

Realizing the nature of technology that evolving on daily basis and the uniqueness of every preservice teacher in their technology, pedagogy, and content knowledge background, the researcher understand 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 could offer a small significant contribution to the field of research in technology use in teacher preparation program and mathematics teaching.

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Mathematics Preservice Teachers' Development of Technology Pedagogical Content Knowledge

예비수학교사들의 테크놀로지 교수내용지식의 개발

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초 록

이 연구는 테크놀로지를 통합한 교사 교육 프로그램을 통하여 예비교사들이 TPCK 개발을 그리고 테크놀로지를 이용하여 학생들을 가르치는 동안 어떻게 그들이 실제교실에서 성공적이었는가를 묘사하였다. 다양한 자료들이 연구 문제를 해결하는데 정보를 제공하기 위해 사용되었다. 결국, 이 연구에서 교사교육 프로그램의 예비교사들이 TPCK를 이해하도록 돕는 것을 강조하는 것이 TPCK의 네 가지 요인에 의해 설명되어지는 예비교사들의 이해로 전이되었다. 하지만 신념, 교수, 테크놀로지 배경의 다양성은 프로그램을 통하여 TPCK의 그들의 이해와 개발에 영향을 주었다.

주요용어 : TPCK, 예비수학교사, 교사 준비 프로그램, 이해, 신념.

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