# Pre-Service Elementary Teachers Planning for Mathematics Instruction: The Role and Evaluation of Technology Tools and Their Influence on Lesson Design

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at George Mason University

By

Christopher J. Johnston
Master of Arts
Concordia University, 2002
Bachelor of Arts
Concordia University, 1998

Director: Dr. Jennifer M. Suh, Assistant Professor
College of Education and Human Development

Spring Semester 2009
George Mason University
Fairfax, VA

DEDICATION

This is dedicated to my grandfather, the Rev. Dr. Martin L. Koehneke, who inspired me to use my God-given talents and follow His plans for my education.

# ACKNOWLEDGEMENTS

I would like to thank my dissertation chair, Dr. Jennifer M. Suh, who encouraged me through every step of this process. Her feedback, patience, and support have meant so much to me.

In addition, I would like to thank the members of the committee, Dr. Patricia Moyer-Packenham and Dr. Margret Hjalmarson, who provided extensive feedback throughout my studies and during the dissertation process.

To my friends and my family, who were so patient with me during the last few years, thank you for your loyalty, patience, and understanding. I couldn't have done it without you.

A special thanks to Janet Holmes for her assistance with the paperwork and logistics throughout my portfolio reviews and defenses. In addition, special thanks to Chip Rogers of the University of Virginia for his assistance with the title of my dissertation, and to David Broyles, Ph.D. for the graphic design of Figure 5.

I would also like to thank my good friend, MSG Salvatore P. Simonetta, Jr. (U.S. Army), who, at the time of my dissertation defense, was deployed and defending my freedom. Thank you for your service to your country and your countrymen.

TABLE OF CONTENTS

## LIST OF TABLES

LIST OF FIGURES

# ABSTRACT

PRE-SERVICE ELEMENTARY TEACHERS PLANNING FOR MATHEMATICS INSTRUCTION: THE ROLE AND EVALUATION OF TECHNOLOGY TOOLS AND THEIR INFLUENCE ON LESSON DESIGN

Christopher J. Johnston, Ph.D.

George Mason University, 2009

Dissertation Director: Jennifer M. Suh, Ph.D.

This qualitative study explored the roles which exist between pre-service elementary teachers and the technology tools they integrate into their mathematics lesson plans. A total of 35 pre-service elementary teachers participated in this study in which the researcher examined their lesson plans and reflection documents.

The project occurred during a one-semester elementary mathematics methods course during which the participants were assigned to plan and teach three lessons, one of which required the use of technology. While writing their lesson plans, participants completed a three-page reflection document to explain their uses of technology. In addition, participants were asked to complete a survey, and selected participants were invited to participate in interviews.

The results of this study suggest seven roles between pre-service elementary teachers and the technology tools they integrate into their lesson plans: Technology Not

Used (TNU), TNU – Willing, TNU – Master, Master, Master – Servant, Servant, and Servant – Partner. Two of these roles, Master and Servant, have already been documented in the literature. The other five roles were identified in the present study. After qualitative analysis, the researcher concluded that access to technology, cooperating teachers, and prior experiences with technology had no significant influence on these roles. The results of the study suggest that curriculum goals do have an influence on these roles. Specifically, pre-service teachers who tended to choose the objective first and used technology to support the lesson objectives were found at the higher end of the hierarchy (Master-Servant, Servant, and Servant-Partner). Conversely, pre-service teachers who tended to give no explicit statement regarding the role of the objective to the lesson plan when selecting technology tools were found at the lower end of the hierarchy (in particular, Master). Participants primarily evaluated their technology tools on the basis of Surface Features (which includes Software Features and Motivation) rather than Content and Instruction (which includes Learning and Mathematics.) Finally, participants primarily identified affordances and limitations of technology tools which focused on Surface Features rather than Content and Instruction. The reflection document completed by the participants has potential for future use by pre-service elementary teachers in their mathematics methods courses.

# 1. INTRODUCTION

## Background of the Problem

As pre-service elementary teachers at this site complete their coursework, they are expected to teach a number of mathematics lessons within the context of their fieldwork schools. During these lessons, teachers may have the opportunity to integrate technology in instruction. There are certainly multiple technology tools available to pre-service elementary teachers: software, virtual manipulatives, applets, websites, and calculators. These technology tools are available for mathematics teachers to use in their mathematics instruction, as demonstration tools, as tools for students to explore concepts, as tools for students to practice skills, and so on. It is assumed that during their methods courses, these pre-service teachers will be exposed to various technology tools. However, little is known about how pre-service elementary teachers evaluate technology tools as they plan for instruction.

The expanding Internet provides numerous technology tools for pre-service elementary teachers to use with their own students. However, because it is available does not mean it is appropriate. Pre-service elementary teachers need experiences in evaluating and using technology to determine which materials are best suited for teaching a particular mathematics topic. Niess (2005) required her pre-service teachers to identify over 60 technology resources for teaching mathematics. The pre-service teachers were required to align the concept or skill taught using technology to the appropriate mathematics and technology standards, thereby forcing them to reflect upon how and why the technology tools should be used in mathematics instruction. The result of this assignment was a "consistent focus in considering the curriculum from a standards base" (p. 522). Rather than simply integrating technology for technology's sake, pre-service teachers considered not only the benefits of the technology, but also the demands of the curriculum and mathematics standards for learning.

## General Statement of the Problem

The purpose of this project was to explore the roles which exist between pre-service elementary teachers and the technology tools they integrate in their mathematics lesson plans. In addition, this project explored how pre-service elementary teachers' conceptions of technology influence the ways in which they evaluate technology tools for mathematical learning, as well as the factors (external and internal) which influenced pre-service elementary teachers' choices of technology tools. For the purpose of this study, the researcher defined roles as interactions between pre-service teachers and technology, and examined how the expectations and beliefs of the pre-service elementary teachers influence how they use technology in their lesson plans.

Through the use of thought-revealing activities, the researcher explored how pre-service elementary teachers' conceptions of technology influence the ways in which they evaluate technology tools for mathematical learning by looking at two critical components of technology evaluation: (1) the criteria pre-service elementary teachers identify and use in their evaluations, and (2) their perceptions of the affordances and limitations of the technology tools. Data were collected from pre-service elementary teachers enrolled in methods courses to address these issues. Thought-revealing activities, in the context of this study, required participants to deliberately reflect upon the choices they make while planning for instruction. Specifically, the researcher was interested in activities which engage pre-service elementary teachers in deliberate and purposeful reflection upon the technology tools they integrate into their lesson plans. The results of this study were used to make recommendations for teacher educators as they plan experiences in their methods courses for pre-service elementary teachers of mathematics.

A pilot study (2008) served as a precursor to the current study. Pre-service elementary teachers ($n$=23) identified their criteria for evaluating technology tools for mathematical learning, and then, using their own criteria, they evaluated three virtual manipulatives selected by the researcher. However, these tools were evaluated outside the context of planning for actual instruction. The researcher therefore desired to know whether or not pre-service elementary teachers' criteria for evaluating technology tools would change when planning for instruction with their own students. In addition, what factors (external and internal) influence pre-service elementary teachers' choice of technology, as well as their evaluations of the technology tools used in lesson plans?

By exploring the roles which exist between pre-service elementary teachers and the technology tools they integrate into their mathematics lesson plans, as well as how pre-service elementary teachers' conceptions of technology influence the ways in which they evaluate technology tools for mathematical learning, this study gives direction to other researchers and educators, particularly those involved in teacher education and the professional development of elementary teachers of mathematics. The researcher notes that the results of this study identified activities which can be integrated into methods courses. Such activities have the potential to engage pre-service elementary teachers in the process of evaluating technology tools, as well as identifying affordances and limitations of technology tools as they plan for instruction.

## Significance of the Problem

A review of the literature yields very few studies which are focused on pre-service elementary mathematics teachers' criteria for evaluating technology tools. Battey, Kafai, and Franke (2005) focused their study on educational software, specifically rational number software. In this study, 35 pre-service teachers identified criteria they would use to evaluate rational number software. Pre-service teachers tended to emphasize surface features (such as clear directions) rather than deep content or instructional features. However, the present study is distinct from Battey, Kafai, and Franke's study, in that they focused on rational number software, whereas the pre-service teachers in the current study also utilized virtual manipulatives, applets, Smart Boards®, calculators, and spreadsheets. The researcher is aware that there may be criteria unique to educational software, and that additional criteria may emerge for these other technology tools. In addition, Battey, Kafai, and Franke did not require pre-service teachers to evaluate the technology in the context of planning for an actual lesson, nor did they ask pre-service teachers to specifically identify the affordances and limitations of the technology tools.

In their study, Kurz, Middleton, and Yanik (2005) developed a taxonomy of software within mathematics education. The five categories are: (a) review and practice tool; (b) general tool; (c) specific tool; (d) environments tool; and (d) communication tool. This study focused on using the taxonomy to instruct pre-service teachers rather than resulting from pre-service teachers' own use of technology. When pre-service teachers have the opportunity to classify various technology tools according to these five categories, *and* they have the opportunity to evaluate the technology tools, they can look beyond the surface features to identify the benefits and constraints of the tools.

One case study examined two pre-service teachers enrolled in a course which introduced them to various kinds of mathematical software (Kurz, Middleton, & Yanik, 2004). The experiences of one secondary pre-service teacher and one elementary teacher indicated that they were able to identify the various features of the technology and explain how these features could benefit student learning. The elementary pre-service teacher experienced similar growth. However, the present study is different from Kurz, Middleton, & Yanik in that a larger population will be investigated, whereas two pre-service teachers were studied. In addition, while the participants were enrolled in a methods course, they were not specifically planning for a lesson they would be teaching with students in their fieldwork placement. Pre-service teachers had no choice in the technology tools they were evaluating; that is, the researchers pre-selected the technology tools to be evaluated. In the present study, pre-service teachers were not limited by the researcher as to which types of technology tools they could use. This present study identified the affordances *and* limitations perceived by pre-service teachers in the context of their own choices for technology use.

The literature also suggests *roles* as a way of classifying the relationships between teachers and the technology they use (Goos, Galbraith, Renshaw, & Geiger, 2003; 2000). These roles include technology as master, technology as servant, technology as partner, and technology as extension of self. (See Definition of Terms, later in this chapter.) These roles may impact how pre-service teachers choose to integrate technology tools for mathematical learning. However, the present study is unique from previous research in that previous research has identified roles for experienced secondary teachers of mathematics. The present study identified roles that exist between pre-service elementary teachers and the technology tools they select for their lesson plans. In addition, content knowledge of secondary mathematics teachers is typically different from elementary teachers due to the requirements of the teaching license and preparation program. The researcher explored the roles that exist between the pre-service elementary teachers and technology in the context of their fieldwork placement.

## Conceptual Framework Guiding this Study

The researcher's conceptual framework can be situated within the work of Stein, Grover, and Henningsen (1996), who explored mathematical tasks within a reform curriculum. These researchers defined a mathematical task as "a classroom activity, the purpose of which is to focus students' attention on a particular mathematical idea" (p. 460). They suggest three phases of mathematical tasks which precede student learning: mathematical task as represented in curricular/instructional materials, mathematical task as set up by the teacher in the classroom, and mathematical task as implemented by students in the classroom (p. 459).

Figure 1 notes the relationships among these various phases, as well as factors which influence the set up and implementation of the mathematical task (Stein, Grover, & Henningsen, 1996, p. 459). Note that the researcher was particularly interested in the second rectangle, “Mathematical task as set up by teacher in the classroom”, and the first oval, “Factors influencing set up.” Specifically, factors which influence the use of technology in mathematical tasks were explored in the present study.

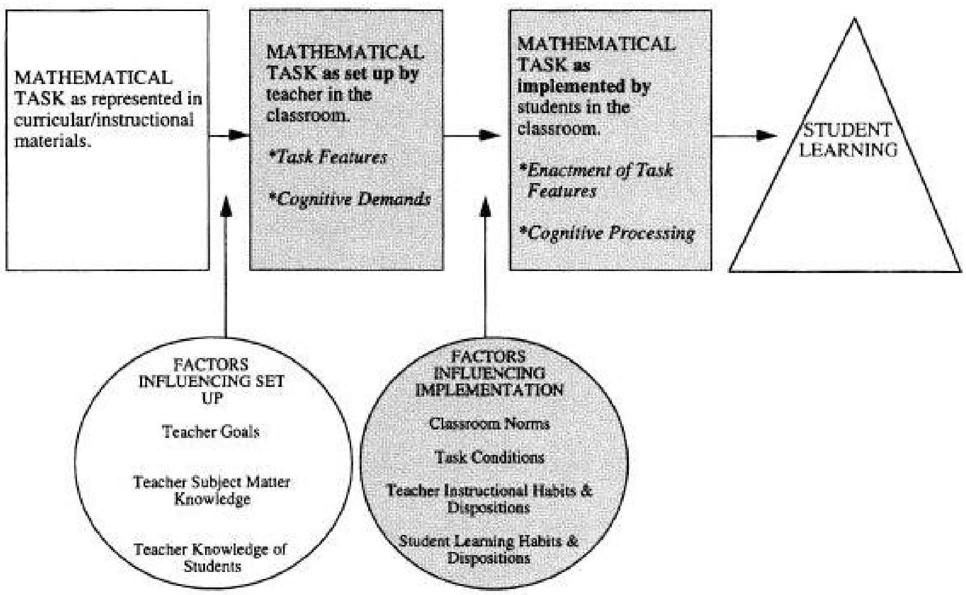



*Figure 1*. Relationship among various task-related variables and student learning (Stein, Grover, & Henningsen, 1996, p. 459).

The researcher recognizes the importance of teacher goals, teacher subject matter knowledge, and teacher knowledge of students. During the present study, he collected data which sought to identify these factors. More importantly, he was interested in various factors which influence the role of technology in mathematical tasks, as shown in Figure 2.

The conceptual framework which guided this study is shown in Figure 2. A narrative explaining this conceptual framework follows the figure.

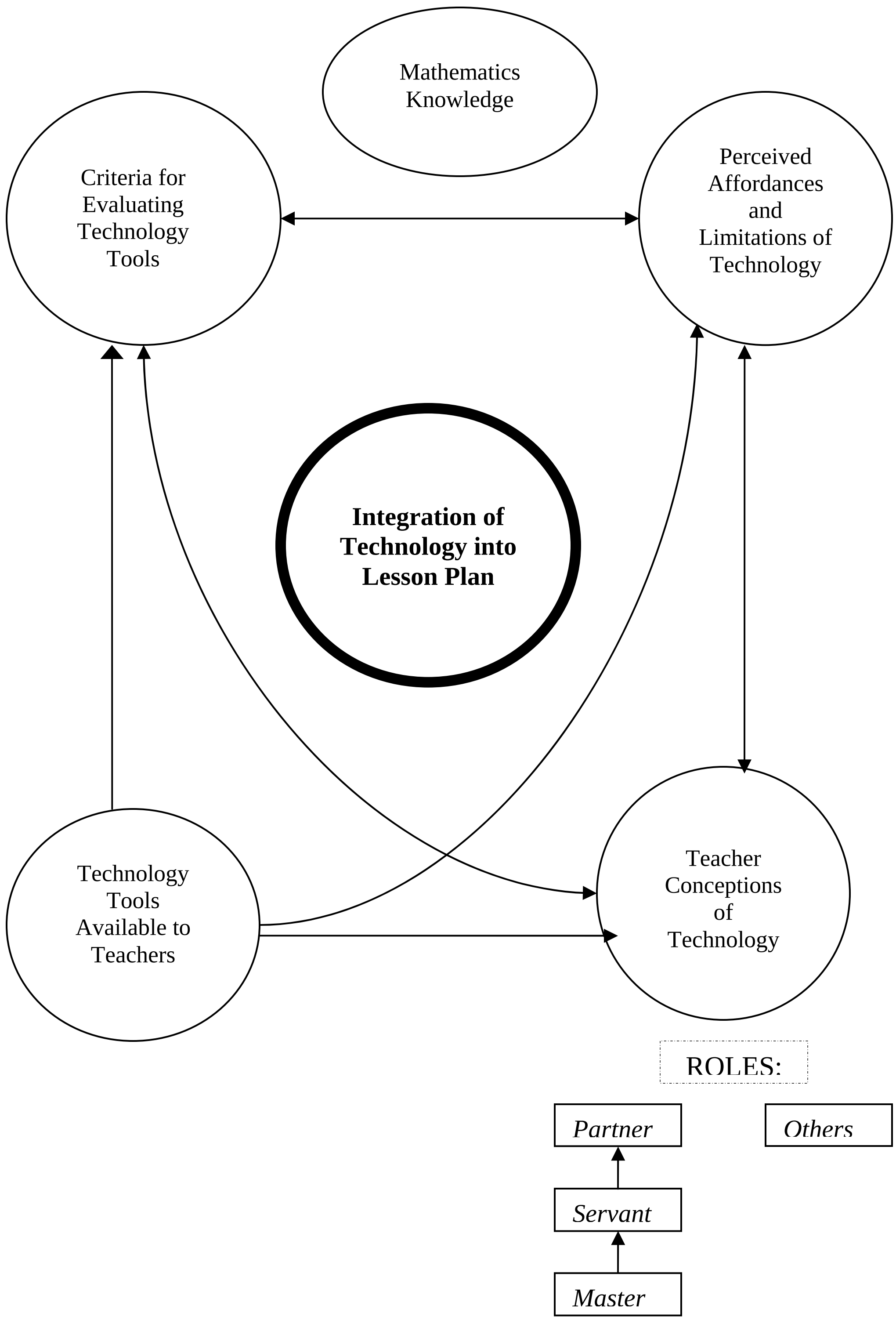



*Figure 2.* Researcher's conceptual framework.

First, it is important to identify some notation and formatting in the conceptual framework. The direction of the arrow denotes the bidirectional relationship of the influence. The “blank” end notes the factor causing influence on the end with the arrow. If there is a double-arrow, this indicates two factors which influence each other. The two curved arrowed connectors were chosen for layout issues only – the curves are not significant.

At the center of the conceptual framework is the concept entitled “Integration of Technology into Lesson Plan.” Surrounding the center main topic are four key sources of influence which were considered in the present study. This conceptual framework visualizes the four key sources of influence for pre-service elementary teachers’ design of lesson plans, as measured in the present study. These four key sources of influence for pre-service elementary teachers were explored by the researcher after they designed mathematics lesson plans which integrate technology. This graphic was designed to illustrate the necessity of all four elements, in light of the research on appropriate technology integration in mathematics education.

Going clockwise from the upper left (for the sake of clarity), the four key sources of influence are: criteria for evaluating technology tools, perceived affordances and limitations of technology tools, teacher conceptions of technology, and technology tools available to teachers. Perceived affordances and limitations of technology are considered to be distinct from criteria for evaluating technology tools in the following manner. Perceived affordances and limitations of technology are those features of the technology tools which are unique to the technology and not available in physical models, physical manipulatives, paper and pencil, or means other than the technology tools identified in this chapter.

Criteria for evaluating technology tools influence and are influenced by perceived benefits and limitations of technology tools, as well as teacher conceptions of technology, and is influenced by technology tools available to teachers. When pre-service elementary teachers identify their own criteria for evaluating technology tools, they focus on particular features which they feel are important. At the same time, they may neglect to identify other features of the technology tool which could be evaluated. For example, if a pre-service elementary teacher identifies multiple representations as a criterion for evaluating the technology tool, they recognize that multiple representations could be an affordance of the technology tool. Thus, their criteria and their perceptions of the affordances and limitations of the technology tool are interrelated. In particular, this study examines how pre-service elementary teachers' criteria for evaluating technology tools are related to the instructional goals for their lesson plans. Battey, Kafai, and Franke (2005) found that pre-service teachers' conceptions of mathematics instruction and technology are not integrated (p. 251). Pre-service elementary teachers may view technology as a standalone activity; the present study explored the existence of this belief among the participants.

Perceived affordances and limitations of technology tools influence and are influenced by criteria for evaluating technology tools, as well as teacher conceptions of technology, and is influenced by technology tools available to teachers. Kurz (2004) found that in the case of two pre-service mathematics teachers, analysis of technology tools for mathematical learning provided the participants with “new knowledge regarding the specific features of software that enable students to learn mathematics, and the fit of those features to particular goals of classroom instruction” (p. 319). The researcher was interested in exploring how the identification of affordances and limitations of technology influences the actual lesson plan, and how pre-service elementary teachers’ personal criteria influence their integration of technology.

Teacher conceptions of technology are a function of the roles between the teachers and the technology, which have been previously identified (Goos, Galbraith, Renshaw, & Geiger, 2003; 2000). Note there is a hierarchy of the roles, which can be used as a classification of such roles: technology as master, technology as servant, and technology as partner. Another role, “Others” was included to identify roles that emerged which did not fit one of these pre-existing roles. Before the start of the study, the researcher recognized the fact that other roles, or perhaps even a new taxonomy, could emerge from the analysis of the data collected in the present study. Technology as extension of self, which has previously been identified in the literature, is rarely found among in-service teachers, so it is not included in this conceptual framework. Note that teacher conceptions of technology influences and is influenced by criteria for evaluating technology tools, as well as perceived affordances and limitations of technology, and is influenced by technology tools available to teachers.

Technology tools available to teachers influences criteria for evaluating technology tools, perceived benefits and limitations of technology tools, and teacher conceptions of technology. Identifying available technology tools is an important component of a methods course, as evidenced by Neiss (2005). In her study, Neiss not only required pre-service teachers to identify resources for teaching mathematics with technology, but teachers also had to align mathematical concepts, which could be taught via technology, with corresponding content and technology standards. However, the researcher was interested in learning how pre-service elementary teachers' conceptions of the technology tools, as well as their own personal criteria for evaluating technology tools, influences the actual lesson plan.

The researcher recognizes the importance of mathematics knowledge for teachers, as noted at the top of the conceptual framework. However, mathematics knowledge for teachers was not a focus of the present study. Thus, it is not connected to the rest of the conceptual framework. At the same time, however, this factor is still incorporated into the conceptual framework because mathematics knowledge was identified by several participants as having influence on the technology tools they selected.

The present study explored how these four major sources of influence, as identified in the conceptual framework, work together as a model of pre-service elementary teacher development. Thus, the research questions follow.

## Research Questions

### *Premises*

Based upon the existing literature, the following seven premises are asserted with regard to pre-service elementary teachers and technology tools for use in mathematics instruction:

1. There is a wealth of technology tools available to pre-service elementary

teachers.

2. Each technology tool carries its own affordances and limitations.

3. When planning for instruction, pre-service elementary teachers use their own criteria for evaluating technology tools.

4. When planning for instruction, pre-service elementary teachers integrate technology based upon their criteria for evaluating technology tools.

5. Different roles exist between pre-service elementary teachers and the technology tools they use.

6. Certain internal factors influence pre-service elementary teachers' integration of technology in lesson plans, including their comfort level and familiarity with the technology, as well as their math content knowledge. These kinds of factors can also be referred to as personal factors, as defined by Patahuddin (2008).

7. A variety of external factors influence technology integration, including, but not limited to, time, requirements of the school and curriculum, and physical availability of technology. These kinds of factors can also be referred to as contextual factors, as defined by Patahuddin (2008).

Thus, these seven premises support the specific targets of research for this project.

*Research Questions*

This project was designed to answer the following research questions:

1) What roles exist between pre-service elementary teachers and the technology tools they choose to integrate in their mathematics lesson

plans?

2) How do various internal factors (which include personal beliefs, as well as prior experiences with technology) and external factors (which include curriculum goals, cooperating teachers, and availability of technology) influence these roles (which may include master, servant, or partner, as well as others) observed between the pre-service elementary teachers and the technology tools?

3) How do these relationships influence the ways in which pre-service elementary teachers plan for mathematics instruction?

   a) When planning for instruction, what criteria do pre-service elementary teachers use to evaluate technology tools for mathematical learning?

   b) When planning for instruction, what perceived affordances and limitations do pre-service elementary teachers identify with respect to technology tools for mathematical learning?

## Limitations and Delimitations

### *Limitations*

The sample size, $n$=35, is relatively small. The results of this study may not necessarily be generalizable to other populations. The results of this study may be unique to this specific population.

In addition, the data collected from this study included lesson plans written by pre-service teachers. The lesson plans collected in this study were one of three written by the participants throughout a semester-long methods course. These lesson plans represent a snapshot of a particular moment during the methods course. Thus, the lesson plans may reflect participants' views of technology at that moment in time, rather than an over-arching view of technology.

*Delimitations*

The researcher realizes that other populations, such as college faculty, beginning teachers, and veteran teachers, could have been potential participants in this kind of study. However, the researcher was specifically interested in pre-service mathematics teachers.

In addition, prior personal experiences with technology, and prior educational experiences with technology (other than in math methods coursework) play a role in pre-service teachers' use and evaluation of technology. The potential influence of these factors was addressed via the use of a survey. The questions on the survey were specifically designed to collect this data without being the focal point of this research study.

Student achievement, which has been the subject of other studies, was not the focus of this project. Data regarding student learning after the lesson has been taught was not collected or analyzed.

Finally, since some of the data collected from this study was based upon only one of three lesson plans written by pre-service teachers (as well as a corresponding instrument), this study did not attempt to document growth over time. Participants' uses of technology may have changed after the conclusion of the semester-long methods course.

*Possible Underlying Variables*

Two models of pre-service teacher fieldwork exist and were part of the present study. In a traditional fieldwork model, pre-service teachers are engaged in a limited number of hours of fieldwork (15 hours per semester in the present study). In a professional development school (PDS) model, pre-service teachers spend full days immersed in an elementary school (4 days per week in the present study). Thus, the fieldwork expectations and experiences of the pre-service teachers could have potentially influenced the ways in which these participants integrate technology within their lesson plans.

Additionally, the pre-service elementary teachers were primarily female, from the same geographic area. All of the pre-service teachers were second-career teachers. These underlying variables, while not the focus of the present study, are important to note at the start of the study.

## Definition of Terms

The following terms are used throughout this dissertation, and their corresponding definitions are described below.

1) Technology tools for mathematical learning include those which are math specific and math support, as defined below.

   Math specific tools include:

- calculators, which are typically four-function calculators in elementary school
- spreadsheets, which are defined as "computerized, numerical record keeping systems that were designed originally to replace paper-based, ledger accounting systems" (Jonassen, Carr, & Yueh, 1998, p. 26).
- virtual manipulatives (such as those found on the National Council of Teacher of Mathematics Illuminations website, http://illuminations.nctm.org or on the National Library of Virtual Manipulatives website, http://nlvm.usu.edu.) Virtual manipulatives offer students multiple representations of physical tools. Moyer, Bolyard, and Spikell (2002) define virtual manipulatives as "interactive, web-based visual representations of dynamic objects that present opportunities for constructing mathematical knowledge" (p. 373).
- applets, which can be standalone versions of virtual manipulatives
- software, which are review and practice tools, or more specific tools, such as Geometers Sketchpad®
- Internet resources for review and practice tools

Math support tools include:

- Smart Boards®, which are interactive whiteboards
- Internet resources, which are review and practice tools, Wikipedias, and other reference materials

2) Roles for technology, as described in greater detail in Chapter 2, include:

- Technology as master: The teacher uses technology "as is" because his or her knowledge of the technology tool is limited.
- Technology as servant: The teacher uses technology to support his or her own teaching style. The teacher does not necessarily incorporate new teaching strategies.
- Technology as partner: The teacher uses technology in a creative way to engage and extend student learning.

3) Technology pedagogical content knowledge (TPCK) for mathematics is defined as "the intersection of the knowledge of mathematics with the knowledge of technology with the knowledge of teaching and learning" (Niess, Lee, Sadri, & Suharwoto, 2006, p.1).

# 2. REVIEW OF THE LITERATURE

## Introduction

As early as 1994, Kaput and Thompson noted the lack of research on technology in mathematics education, specifically in the *Journal for Research in Mathematics Education.* In recent years, studies have inventoried pre-service teachers' attitudes toward technology and mathematics (as well as other subject areas). Other studies have focused on the effects of technology on student learning. Some of the existing literature does address the role of technology integration in coursework and methods courses, but only with respect to general teacher preparation, not specifically mathematics. Other parts of the literature have focused on how elementary mathematics students can benefit from using technology within their own classrooms. However, there is little research which addresses the issue of how pre-service teachers evaluate technology tools for mathematical learning.

The purpose of this chapter, therefore, is to present a synthesized review of the literature related to the research questions of this research project. First, the chapter begins with a statement of significance of technology in mathematics education. Second, the chapter identifies available technology tools for mathematical learning and the ways of classifying these tools. Third, the chapter presents an overview of the limited research on teachers' evaluation of technology tools for mathematical learning. Fourth, the chapter discusses appropriate uses of technology in mathematics education. Fifth, teachers' roles for technology, as suggested by the literature, are discussed. And finally, the development of identity of pre-service mathematics teachers is addressed.

## Approach

Multiple exhaustive searches of the ERIC database were performed for the period 2000 through 2009. The following keywords were used when performing the searches: technology, mathematics, preservice, preparation, professional development, planning, teachers, and evaluation. Once articles were identified, their reference lists were consulted for additional articles which could be used for this literature review.

## The Significance of Technology in Mathematics Education

Technology has become a part of the elementary school curriculum, as technology coordinators and department chairs have struggled with the best model for integration of technology for student learning. What benefits do technology tools have on student mathematical learning? As early as 1989, Fey identified some key results of calculator and computer usage in mathematics. Students who used these tools showed improve attitudes about learning mathematics, increased confidence in their own mathematical abilities, and demonstrated more persistence in problem solving. He further identified a major affordance of computer technology: the ability to represent abstract mathematical concepts.

Bitter, Hatfield and Edward (1998) suggest ten characteristics of using computer tools to enhance learning:

1. Promotes active versus passive learning.

2. Offers models or examples of exemplary and nonexemplary instruction.
3. Is illustrative and interactive.
4. Facilitates the development of decision making and problem solving.
5. Provides user control and multiple pathways for accessing information.
6. Provides motivation and allows for variability of learning styles.
7. Facilitates the development of perceptual and interpretational abilities.
8. Offers efficient management of time for learning and less instructional training time.
9. Allows for numerous data types.
10. Offers multilingual presentation. (p. 106)

Thus, technology tools have numerous affordances which pre-service teachers need to identify and evaluate as they consider using them in their own instruction.

In recent years, researchers have identified TPCK (technology pedagogical content knowledge) as a framework for studying teachers' (both pre-service and in-service) knowledge for teaching mathematics with technology (Mishra & Koehler, 2006; Niess, Lee, Sadri, & Suharwoto, 2006). Simply knowing a technology is not enough for teachers to use that technology with their own students. Rather, teachers must consider technology, pedagogy, and content when planning for mathematics instruction with technology. Further discussion about TPCK will follow in the sixth section (below), "The Development of Identity of Pre-Service Mathematics Teachers."

*Computers as Mindtools*

Jonassen, Carr, and Yueh (1998) recognized the potential for computers to engage students in activities beyond simple computations. They define mindtools as “computer applications that, when used by learners to represent what they know, necessarily engage them in critical thinking about the content they are studying” (p. 24). For example, spreadsheets can be considered as mindtools because students can represent, reflect on, and calculate numerical information (p. 26). Notice that spreadsheets are not limited to simple numerical calculations. Students can explore the “what if” by altering values entered into cells and noting the impact of such changes. Students can also use spreadsheets to create programs, thereby becoming rule-makers themselves. Other examples of technology tools which can be considered mindtools will be discussed later in this chapter.

Zbiek, Heid, Blume, and Dick (2007) identify cognitive technologies for mathematics education as technologies which are used for “technical or conceptual dimensions of mathematical activity” (p. 1171). Cognitive tools for mathematics allow students to expand their own thinking and understanding of a mathematical situation or problem. They further identify three particular features (constructs) of cognitive tools for mathematical learning: externalized representation, mathematical fidelity, and cognitive fidelity. These three constructs will be discussed in further detail in Chapter 3.

*NCTM Principles and Standards*

What is the significance of the National Council of Teachers of Mathematics (NCTM) Technology Principle? According to national professional teacher education organizations, what are the desired outcomes of mathematics teacher preparation programs in regard to technology? These are questions which are addressed in this section.

The Technology Principle, as set forth by the National Council of Teachers of Mathematics (2000), includes three secondary principles, which correspond to guidelines that will be set forth later in this chapter. These three secondary principles state that:

- Technology enhances mathematical learning.
- Technology supports effective mathematics teaching.
- Technology influences what mathematics is taught (p.25-26).

Pre-service teachers should take these 3 principles into consideration when planning for instruction with technology.

*Pre-Service Mathematics Teachers' Coursework*

Knowledge of technology is one of the 14 NCATE/NCTM Program Standards for Programs for Initial Preparation of Mathematics Teachers (2003). As the standard states, "Candidates embrace technology as an essential tool for teaching and learning mathematics," and this is indicated by teachers who "use knowledge of mathematics to select and use appropriate technological tools" (p. 3).

The Association of Mathematics Teacher Educators (2006) also recognizes the impact of technology on mathematics education. In their position statement, they note the following desired skills of mathematics teachers upon completion of their teacher preparation programs:

- demonstrate flexibility with high-quality and creative instructional techniques, both with and without technology, to help students explore and learn mathematics, develop mathematical thinking and communication abilities, and solve complex real-world problems;
- understand, by reflecting on how technology affords and constrains student actions and thoughts, when and how use of technology can advance learning and critical thinking, and when it can hinder the mathematical development;
- efficiently troubleshoot technology difficulties in both student and teacher use; and
- incorporate a variety of assessment techniques, including the use of technology to evaluate students' understanding of important mathematical concepts (p. 2).

Thus, the significance of technology in mathematics education is recognized by these major national bodies for teacher preparation and supported by the existing literature.

## Available Technology Tools for Mathematical Learning

### *Five General Categories of Software*

For the purposes of this paper, technology refers to technology tools for mathematical learning. As defined in Chapter 1, technology tools for mathematical learning include calculators, spreadsheets, virtual manipulatives, applets, software, Internet resources, and Smart Boards®. While productivity software, such as word processing and presentation tools can be used by students, they are not necessarily tools for mathematical learning. Numerous technology tools are available for teachers of mathematics to integrate within their lessons. However, pre-service teachers need to become good “consumers” of the technology resources available to them.

Kurz, Middleton, and Yanik (2005) developed a taxonomy of software within mathematics education. The taxonomy can be expanded to almost any form of technology, not just software. The five categories are:

- Review and practice tools
- General tools
- Specific tools
- Environments tools
- Communication tools

Each of these categories is explained in further detail below.

*Review and practice tools.* This type of software is used by students to review previously learned material; no new concepts are introduced. Students are drilled on specific skills in a particular content area, such as mathematics. Kurz et al. noted that this is a common type of technology used by mathematics teachers (2004). This technology has been present in the classrooms for many years, so most teachers are familiar with this type of tool.

*General tools.* When the software can be used for various mathematics topics, it can be classified as general. It can be used across grade levels and for different applications. The teacher must develop the lesson to ensure that the technology is used to support the learning objectives of the lesson. Examples of this type of technology would include spreadsheets. Spreadsheets, while originally designed for business applications, have made their way into the classroom for creating tables and graphs, as well as other mathematical applications.

*Specific tools.* A specific tool is used to teach and/or learn one specific topic or skill. In this category, the software or technology focuses on a new concept or skill, unlike review and practice tools, which do not introduce new ideas. Examples of this type of technology could include virtual manipulatives and applets, which can be used to explore new concepts or skills. Specific tools can also be classified as representations, as students learn new material through various representations (such as those afforded by virtual manipulatives.)

*Environments tools.* In this model, different types of learning in several subject areas are combined. Students investigate and explore in a new environment, one which is not possible in a typical classroom. Examples include online simulations, microworlds, and applications such as Star Logo.

*Communication tools.* Students share information with other students, their teacher, as well as (potentially) students and teachers in other classrooms around the world. Students develop mathematical understanding as they participate in discourse. These tools may not be math specific and could potentially be used in all content areas. Examples of communication tools include chat and asynchronous discussion boards, such as Blackboard. While this type of tool may be found at the pre-service teacher education level, it is not as common at the elementary or middle school level.

When pre-service teachers have the opportunity to classify various technology tools according to these five categories, and they have the opportunity to evaluate the technology tools, they can look beyond the surface features to identify the affordances and constraints of the tools. In one case study of two pre-service teachers, these teachers were enrolled in a course which introduced them to various kinds of mathematical software (Kurz et al., 2004). The experiences of one teacher indicated that she was able to identify the various features of the technology and explain how these features could benefit student learning.

Handal and Herrington (2003) identified their own categories for computer-based tools in mathematics education. They include: drills, tutorials, games, simulations, hypermedia, and tools and open-ended learning environments. Drills, tutorials, and games can all be classified as review and practice in the previously-mentioned taxonomy. Hypermedia could be classified as specific, and tools/open-ended learning environments would fall under the environment category. Thus, the taxonomy identified by Kurz et al. (2005) is more complete and appropriate for use with pre-service mathematics teachers.

## Teachers’ Use and Evaluation of Technology Tools for Mathematical Learning

The ability to classify software and other technology tools is an important skill for mathematics teachers. However, even more critical is the evaluation and selection of technology tools for use within mathematics instruction. Battey, Kafai, and Franke (2005) studied pre-service teachers’ criteria for evaluating and using mathematical software. They found that most pre-service teachers focused on surface features, such as clear directions, rather than focusing on the content or pedagogical issues. Learning was important, but statements made by the pre-service teachers indicated a concern for general learning, rather than learning important mathematical content. Finally, motivation was a key factor when selecting mathematical software. Overall, pre-service teachers were concerned about engaging and motivating software.

The results of this study suggest that pre-service teachers consider technology and mathematical learning to be two distinct components, and that pre-service teachers select software on the basis of student motivation and clear directions given by the software program. Thus, technology is considered to be separate from instruction, a ‘stand-alone’ activity. This furthers the argument that pre-service teachers need guidance when using technology in their mathematics instruction, and that pre-service teachers need to deliberately reflect upon their criteria for evaluating technology tools.

Other literature supports the idea that teachers tend to focus on surface features when evaluating technology tools for mathematical learning. Kafai, Franke, and Battey (2002) note that 95 reviews of software, which were written by in-service teachers, offer little information about mathematical learning and tend to focus on surface features of the software. Teachers did not evaluate the software in light of NCTM Standards, goals for learning, or other mathematical criteria. Rather, they evaluated the software based on ease of use, how much students liked the software, and other similar features.

The results of the researcher’s pilot study (2008) suggest that pre-service teachers tend to emphasize surface features over content and pedagogical features. In a study of 23 pre-service elementary teachers, the researcher found that, when evaluating virtual manipulatives, the participants identified the following criteria: software features (46%), motivation (10%), mathematics (11%), and learning (33%). Thus, mathematics features of the technology tools were less important to the pre-service teachers than software features. However, the participants of this study were not asked to specifically identify the affordances and limitations of the technology tools. Nor were they engaged in lesson planning. Therefore, more research is needed within the context of planning for instruction.

## Four Roles for Technology

As teachers use and evaluate technology resources available to them, certain roles can be established between the teachers and the technology tools. Four roles for technology have been suggested by the literature (Goos, Galbraith, Renshaw, & Geiger, 2003; 2000). In a three-year longitudinal study of secondary school mathematics classrooms, graphing calculators and overhead projectors were identified as the most often used technology tools by in-service teachers (Goos, et al., 2003). Four roles for technology in teaching and learning are suggested by their research: master, servant, partner, and extension of self. These four roles are explained in detail below.

### *Technology as Master*

"Here the teacher is subservient to the technology and is able to employ only such features as are permitted either by limited individual knowledge or force of circumstance" (Goos, et al., 2000, p. 307). In this case, technology use is limited because of the comfort level or familiarity of the instructor. One instructor in the study used technology because of syllabus requirements. However, his students were not allowed to use technology to explore any mathematical knowledge beyond the limited experiences created by the instructor.

*Technology as Servant*

The user implements technology to support his or her teaching style. New teaching strategies are not necessarily incorporated by the teacher. In this case, technology is often used to replace work which typically is done by hand (e.g. computation and graphing.) Technology is not necessarily used for concept exploration or development, nor is it used in a creative manner to change the type of activity students would typically complete in the instructor's course.

*Technology as Partner*

The teacher does not use technology to control the learning experiences; rather, the technology is used in a creative way to engage and extend student learning. Students tend to be in more control of their learning, rather than passive recipients of information. In this role, technology may also be used to encourage mathematical discussion. For example, the teacher or student may pose mathematical conjectures via the use of technology (e.g. graphing calculator) for other students to consider in the context of a whole-class discussion.

*Technology as Extension of Self*

While this is the highest level of functioning, it is rarely seen in the research. An example of technology as extension of self would be "writing courseware to support and enhance an integrated teaching program" (Goos, Galbraith, Renshaw, & Geiger, 2000, p 308). Similarly, teachers who design applets for their students to use would be at this level. Mishra and Koehler (2006) have used technology design-based activities in their elementary and secondary teacher preparation courses as a means of developing these pre-service teachers' TPCK. Further research is needed to determine if these pre-service teachers continue to design technology (i.e. programming) once they are in their own classrooms to determine if they are operating at the Technology as Extension of Self level.

*Discussion of These Roles*

As Goos, Galbraith, Renshaw, and Geiger (2003) note, these roles are not static. The roles can change depending upon the mathematics content, the technology tool itself, and other experiences with technology. The researchers also note the impact of the teachers' pedagogical beliefs on their use of technology. The present study is not specifically interested in the role of collaborative inquiry, but these researchers note the potential for increased collaboration in technology infused classrooms.

The results of the pilot study preceding the present study (2008) suggest that technology as master and technology as servant are the predominant roles found in pre-service teachers. In a study of 21 pre-service elementary teachers (two participants were not included in this portion of the data analysis), participants were identified with the following roles: technology as master (29%), and technology as servant (62%), and technology as partner (10%). However, these pre-service teachers were identified on the basis of their evaluations of three pre-selected technology tools, and they were not engaged in lesson planning during this study. Thus, further research is needed to determine the roles of technology and how they impact pre-service elementary teachers as they design lessons.

## Appropriate Uses of Technology in Mathematics Education

### *Guidelines for the Use of Technology*

One aspect of the development of pre-service mathematics teachers is understanding the appropriate uses of technology. Once they know what tools are available to them, pre-service teachers need to know when and how to use technology appropriately. While this may appear to be a point which need not be made, it is critical that teacher preparation programs make a concerted effort to guide pre-service teachers as they select and use technology tools. Simply giving pre-service teachers technology without considering the implications of the technology will not, in itself, increase student learning. Pre-service teachers must have experiences which enable them to integrate technology into their mathematics lessons in such a way that the focus is on the mathematics, not the technology.

Five guidelines for appropriate uses of technology were identified by Garofalo, Drier, Harper, Timmerman, and Shockey (2000) and are specific to mathematics education:

- Introduce technology in context
- Address worthwhile mathematics with appropriate pedagogy
- Take advantage of technology
- Connect mathematics topics
- Incorporate multiple representations (p. 67).

These five guidelines are explained in further detail below. These guidelines should be taken into consideration by pre-service teachers as they plan for instruction.

*Introduce technology in context.* In some school settings, teachers may identify a technology tool, and then build a lesson around the technology itself. Garofalo et al. suggest that the learning objectives be identified first, and then appropriate technology should be incorporated in such a way that the learning objectives are met. “The use of technology in mathematics teaching is not for the purpose of teaching about technology, but for the purpose of enhancing mathematics teaching and learning with technology” (Garofalo et al., 2000, p. 68).

*Address worthwhile mathematics with appropriate pedagogy.* Mathematics content should not be taught simply because technology allows it; rather, worthwhile mathematics should be taught because it meets the curricular goals and needs of the students. In addition, pedagogy should be considered when teaching using technology. Students should not use calculators to perform calculations or other tasks without having an understanding of the mathematics involved. Thus, technology should not be used as a substitute for learning. At the same time, however, technology such as Geometers Sketchpad or spreadsheets, can be used as a way of developing students’ conceptual understanding of mathematics. A word of caution is necessary: simply adding more technology features can distract from the important mathematics involved. For example, Garofalo et al. (2000) identify “adding so many bells and whistles into a Power Point slideshow that the mathematics gets lost” (p. 69) as an example of not addressing worthwhile mathematics with appropriate pedagogy.

*Take advantage of technology*. When teaching mathematics using technology, teachers should strive to design activities which “extend beyond or significantly enhance what could be done without technology" (Garofalo et al., 2000, p. 71) rather than simply teaching the same content in the same manner as done previously. In addition, teachers can use technology to allow students to explore mathematics in more depth, as well as in a more interactive way. Finally, more topics can be taught once the computational constraints are lifted. (As mentioned in the previous section, however, students must still have an understanding of the basic procedures the technology is performing.)

*Connect mathematics topics.* Often the mathematics curriculum, especially at the high school level, is segmented, even within the context of mathematics. For example, algebra, geometry, trigonometry, and other content courses, are considered separate mathematics courses. Even in the middle school curriculum, students can be aware of this separation (for example, students may note, via their textbook's table of contents, separate chapters on probability, geometry, and the like.) "Technology-augmented activities should facilitate mathematical connections in two ways: (a) interconnect mathematics topics and (b) connect mathematics to real-world phenomena" (Garofalo et al., 2000, p. 73).

*Incorporate multiple representations.* Technology can be used to assist students as they make connections between verbal, graphical, numerical, and algebraic representations. Technology can both increase the number of representations available to students, as well as enhance the quality of these representations. For example, the concept of fractions is one rich with potential representations. As Chinnappan (2000) suggests, there is little research on how teachers use software that allows for visual representations of fractions. What kinds of representations do teachers use? How do these representations affect student learning? These are important questions.

As teacher education faculty design coursework and experiences, it is important that these five principles are integrated within the mathematics education experiences of pre-service teachers. These guidelines apply to content courses, methods courses, field experiences, and student teaching. These five guidelines are not the only guidelines suggested by the research. Flores, Knaupp, Middleton, and Staley (2002) identified six guidelines for the integration of technology, science, and mathematics:

1. Technologies are only tools.
2. Technologies should enable students to do what they could not do without them.
3. Technologies must be on hand all the time.
4. Tools should facilitate the creation of sharable, modifiable, transportable models of mathematical and scientific concepts.
5. Sharing of data/resources should be simple.
6. The setup of the workstations should facilitate collaboration between students.

Notice that guidelines 1, 2, and 4 correspond to some of Garofalo et al.'s guidelines. The other three guidelines are more technical in nature and deal with design issues.

*Models of Pre-Service Teacher Programs*

The guidelines suggested above are intended both for pre-service and in-service teachers. Garofalo et al. (2000) identify the approaches of teacher educators to integrate technology into their teacher preparation programs by categorizing these approaches according to the end user of the technology, whether that is the teacher educator (faculty), pre-service teachers, or ultimately students. In the case of the teacher educator, the faculty member in the college of education uses various multimedia resources, such as videos and case studies, as a means of analyzing teaching episodes. Those teacher education programs which prepare the teacher to be the primary user of technology focus on technology productivity tools (word processing and the like) and/or subject-specific software and websites for creating presentations, lessons, and assessments (Garofalo et al., 2000). Finally, those teacher education programs which are preparing pre-service teachers to use technology in such a way that their own students will take advantage of technology as they explore concepts and solve problems focus on guiding the pre-service teachers in appropriate uses of technology in the context of a particular subject area.

Duhaney (2001) suggests four models of teacher preparation programs which posit to integrate technology in their programs. Duhaney's work is based upon earlier work done by Gillingham and Topper (n.d.) The four models include:

1. Single course approach: One course on technology is taught as a requirement for successful completion of the teacher preparation program.
2. Technology infusion approach: Technology is incorporated in each course in the teacher preparation program.
3. Student performance approach: The final responsibility of technology knowledge is placed on students, rather than on faculty.
4. Case-based approach: Pre-service teachers study cases of teachers who are

> already integrating technology into their instruction to determine "best practices" and reflect upon these case studies (Duhaney, 2001, p. 26-27).

Notice that the first three models suggested by Duhaney correspond fairly well to the three models for teacher preparation programs as suggested by Garofalo et al.

## The Development of Identity of Pre-Service Mathematics Teachers

### *Attitudes of Pre-Service Teachers Toward Technology*

Pre-service teachers enter a teacher preparation program with a number of attitudes and beliefs about technology and mathematics instruction. They have concerns about using technology, and their previous experiences with technology (both personally and in their own schooling) can impact these concerns. The goal of a teacher preparation program, according to Hazzan (2000), therefore should be "on the one hand, to help the prospective teachers cope with their concerns, and on the other hand, to encourage them to be guided by their beliefs when they feel that the integration of computers in mathematics classes may improve the learning of mathematics on the part of their pupils" (p. 7). Thus, teacher educators need to take into account pre-service teachers' existing beliefs, concerns, and attitudes when developing their coursework and experiences.

One way to address pre-service teachers' concerns, beliefs, and attitudes is to explore their arguments for and against using technology on a number of dimensions. Hazzan (2003) suggests a two-dimensional scheme for capturing pre-service teacher arguments for and against using technology in mathematics instruction. One dimension describes the components of the lesson, which include learner, teacher, mathematical content, learning environment, and class atmosphere. The other dimension describes the psychological aspects, which include cognitive factors, affective factors, and social factors. Note how some of these concerns, beliefs, and attitudes can be situated within Figure 1. Some of these could be considered internal and external factors related to pre-service teachers' reasons for integrating (or not integrating) technology in their lesson plans.

Once pre-service teachers have articulated their arguments for and against using technology on the basis of the components of the lesson and the psychological aspects, these arguments can be used as a starting point for teacher educators as they develop their coursework and experiences for the pre-service teachers. Hazzan (2003) noted that many of the pre-service teachers in his study made the following comment: "It is worth integrating learning with computers together with learning and teaching without computers" (p. 222). This would suggest that pre-service teachers seek a balance when using technology in their own instruction.

Pre-service teachers' coursework and experiences can be used to change their attitudes toward using technology in mathematics instruction. In one methods course, Li (2005) required her students to create a multimedia project which they would use in their own fieldwork. One pre-service teacher, "David", created a multimedia project, and it "inspired him to examine the newly acquired knowledge in field classrooms, which allowed him to observe its impact on students and the cooperating teacher. Witnessing such impact, consequently, affected his beliefs and attitudes" (Li, 2005, p. 222). As pre-service teachers witness an impact on students and student learning, their own beliefs and attitudes toward technology in mathematics instruction will be impacted.

In addition to attitudes toward integrating technology, pre-service teachers' experiences can impact their attitudes toward math itself and the content they will be expected to teach. Li (2005) found that for some of the pre-service teachers in her study, the creation of a multimedia project which focused on geometry had a positive impact on their attitudes toward geometry and teaching geometry. Thus, an added benefit of integrating technology in mathematics instruction is improved attitudes toward the content and pedagogy.

Ross, Hogaboam-Gray, McDougall, and Bruce (2002) noted similar results. Their study focused on technology and its contribution to the implementation of mathematics education reform in three primary school teachers. Across the three teachers in the case study, two major results were noted: technology expanded the scope of their program, and it increased positive attitudes among the participants. These teachers saw immediate results in their own students as the students used various technology tools, and this impacted the teachers' attitudes toward technology and mathematics teaching in a positive way.

*Professional Knowledge and Identity*

As previously stated, the attitudes of pre-service teachers play an important role in their use of technology with their future students. As pre-service teachers gain experience in teaching and using technology, they begin to develop their own professional identity. Ideally, as pre-service teachers develop, they will not simply mimic the experiences they had in their own education. Rather, they should begin to develop their own professional identities. In a case study, Goos (2005) documented the growth of one pre-service mathematics teacher. The results of the study indicate that the pre-service teacher became an active participant in his development as a teacher. He did not simply mimic his professors; instead he considered the implications of technology in light of his own belief structure and goals as he progressed through his teacher education program. Further research into the factors which affects this kind of development would be worthwhile.

Pre-service teachers develop their professional knowledge across several dimensions: technology, pedagogy, and content. Learning and teaching mathematics with technology is not a new concept, but the intersection of technology, pedagogy, and content is. DaPonte, Oliveira, and Varandas (2002) indicate:

> As ICT [Information and Communication Technology] changes the environment in which teachers work and the way they relate to other teachers, it has an important impact on the nature of teachers' work and therefore on their professional identity. The development of a professional identity involves assumption of the essential norms and values of a profession…A mathematics teacher should be able to carry out the proper professional activities of the teacher and identify personally with the teaching profession. That means assuming a teacher's point of view, internalizing the teacher's roles and ways of dealing with professional issues (p. 96).

Pre-service teachers, therefore, develop a professional identity in light of technology and its impact on mathematics instruction.

*Developing Technology Pedagogical Content Knowledge*

The professional identity of pre-service teachers, as it relates to technology, develops throughout their academic career. This development of professional identity can be considered from the standpoint of technology pedagogical content knowledge. The concept of a technology pedagogical content knowledge (TPCK), also referred to as technological pedagogical content knowledge (Mishra & Koehler, 2006) for pre-service mathematics teachers can be defined as "the intersection of the knowledge of mathematics with the knowledge of technology with the knowledge of teaching and learning" (Niess, Lee, Sadri, & Suharwoto, 2006, p. 1). Simply put, TPCK is knowing how and when to use technology within the context of a rich mathematical learning environment. TPCK is concerned with the interaction between technology, mathematics, and good teaching practices. It seeks to answer questions such as: How does technology impact the content? How does technology impact the teaching of that content? What considerations must a teacher make when planning a lesson which uses technology? A pre-service teacher must have experiences which allow him or her to develop learning situations in which technology is infused in a pedagogically sound manner in light of the mathematics being taught.

Niess (2005) notes that learning mathematics with technology is different from learning how to teach mathematics with technology. Using technology in a content course, such as mathematics, does not guarantee that pre-service teachers will know how to use that technology in their own teaching. For example, a class which teaches pre-service teachers how to use spreadsheets in isolation will not necessarily develop their technology pedagogical content knowledge (TPCK). In addition to knowing the content (mathematics), the pre-service teachers must have a solid foundation in pedagogy, as well as technology and how it relates to the teaching of elementary mathematics. Teacher preparation courses must consider how the three components of TPCK interact with one another. Further, Kersaint, Horton, Stohl, and Garofalo (2001) found that pre-service teachers of mathematics at the elementary and middle school levels aren't necessary receiving instruction and experiences in how to integrate technology within their own mathematics lesson plans.

While pedagogical content knowledge is not a new concept (Shulman, 1986), research in technology pedagogical content knowledge is relatively recent. Mishra and Koehler (2005) have attempted to measure the development of TPCK via surveys in their teacher preparation programs. In their experiences, pre-service teachers "moved from considering technology, pedagogy, and content as independent constructs toward a more transactional and codependent construction that indicated a sensitivity to the nuances of technology integration" (p. 1043). Pre-service teachers were engaged in technology-by-design activities, which influenced their changes in thinking. For example, one such activity might include redesigning educational web sites. More research is needed as pre-service teachers develop their own construct of technology pedagogical content knowledge.

One component of TPCK is the appropriate selection of technology for mathematical learning. The graphing calculator, for example, is one technology tool that has been available to mathematics teachers for over 20 years. Kastberg and Leathem

(2005) identify three themes in the literature, with specific reference to graphing calculators: access to graphing calculators, the place of graphing calculators in the curriculum, and the relationship of graphing calculators to pedagogy. Access refers to the ability of students to use the graphing calculator in their mathematics classes. Depending upon the beliefs of the teacher, students may or may not have access to graphing calculators. For example, if the teacher believes that students should first master graphing functions by hand, then the graphing calculator is not present for all instruction. On the other hand, if the teacher believes that the graphing calculator can be used to develop mathematical concepts, then students will have open access to graphing calculators.

How much access should students have to graphing calculators? What is the place of the graphing calculator in the mathematics curriculum? How does pedagogy impact student learning? Notice that “graphing calculator” could potentially be replaced with any mathematical technology, and the questions would still be pertinent. As pre-service teachers develop their technology pedagogical content knowledge, they begin to address these questions. Kersaint (2007) notes that Mishra and Koehler’s (2007) description of TPCK does “not address an important aspect of mathematics education that must be considered – the curriculum. A teacher’s knowledge of the curriculum…influences student learning, as the decisions teachers make about the curriculum can either enhance or hinder access to important mathematical topics” (p. 257). Thus, teacher education courses must address the issue of curriculum with respect to pre-service teachers’ TPCK.

Research has shown that teachers’ attitudes toward technology can be influenced by their knowledge of the technology itself. For example, in a case study of one experienced secondary mathematics teacher, Doerr and Zangor (2000) noted the following results: “The teacher’s confidence in her own knowledge and skills and skills and her own flexible use of the calculator led to a classroom environment where students were free to use their calculators as they wanted and were actively encouraged to use them to calculate, explore, confirm, or check mathematical ideas” (p.159). In addition, the teacher believed that the graphing calculator could be used to help students build meaning for the mathematics they were studying. The teacher was aware of some of the limitations of the graphing calculator, and she designed activities and questions to help students overcome these limitations.

Further, teacher knowledge of mathematics can influence their use and selection of technology tools with their students. In his study, Monaghan (2004) noted that “use of technology might generate mathematical output that the teachers did not understand and that this could impact on teachers’ practice, e.g. ‘I’m not going to do that topic with the class because I can’t explain the software’s solution’” (p. 338). Further, work with technology can identify weaknesses in the mathematical content knowledge of teachers, as noted by Monaghan. If a teacher does not understand how the technology arrived at a solution, he or she may be less willing to use the technology.

Closely related to teachers’ mathematical knowledge is a distinction between teaching the technology and teaching mathematics *with* technology. Monaghan (2004) found that three of the teachers in his study were concerned that their students were attending to technological details when using technology, rather than attending to the mathematics concepts in question. One teacher, in particular, found her students were so focused on correctly formatting the cells of a spreadsheet, that they were not focused on important mathematical learning. While this study involved mathematics teachers at the secondary level, one could see how similar concerns could be expressed by elementary teachers of mathematics.

*Four Outcomes of Pre-Service Mathematics Education*

Thus, as pre-service teachers develop their professional identities, which are impacted by their technology pedagogical content knowledge, it is expected that certain outcomes will naturally follow. Niess (2005) suggests four outcomes for TPCK development in a teacher preparation program:

1. An overarching conception of what it means to teach a particular subject integrating technology in learning;
2. Knowledge of instructional strategies and representations 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 (p. 511).

These four desired outcomes suggest that teacher preparation programs should guide the thinking and development of pre-service mathematics teachers toward a more global perspective of what it means to integrate technology in mathematics education.

In one case study (Niess, 2005), a pre-service teacher embraced technology in her student teaching experience. For this pre-service teacher, technology afforded her students the opportunity to conceptualize math in a new way, allowed her students to be more efficient with their computations, and gave them opportunities to solve real-world problems. However, as in the case of many pre-service teachers, this teacher's lessons often focused on the technology tool itself, and not the mathematics. Thus, students may not necessarily make the connection between the mathematical concept and their in-class experiences as the teacher had originally intended. This pre-service teacher's conception of what it means to teach mathematics with technology was still developing.

Another issue facing pre-service teachers is knowing how students understand, think about, and learn mathematics with technology. Pre-service teachers tend to focus on their own teaching and think less about the students (Niess, 2005). Pre-service teachers need to take the opportunity to reflect upon the students' understanding, thinking, and learning as technology is integrated. In Niess's study, a guiding question for the student teachers as they planned instruction with technology was, "How will the students understand the concepts in the technology-enhanced instructional activity?" (2005, p. 521). This question ought to be a guiding question as pre-service teachers plan for instruction.

Many technology tools are available for mathematics teachers to use in their instruction. The Internet provides numerous websites, software, virtual manipulatives, applets, and the like for teachers to use with their own students. However, just because it is available does not mean it is appropriate. Pre-service teachers need experiences in evaluating and using technology to determine which materials are best suited for teaching a particular topic. In one assignment in a teacher preparation program, Niess (2005) required pre-service teachers to identify over 60 technology resources for mathematical learning. These pre-service teachers then identified appropriate content standards and technology standards. As a result of this assignment, pre-service teachers deliberately reflected upon appropriate technology use for mathematical learning, considering both the how, when, and why of technology integration.

*Summary*

The major models of mathematics teacher education have some similarities and differences among them. Figure 3 shows a comparison of five guidelines for the use of technology in mathematics education, as established by Garofalo et al. (2000) with the other models suggested in this chapter.

| Garofalo, Drier, Harper, Timmerman, & Shockey (2000) | Flores, Knaupp, Middleton, & Staley (2002) | Niess (2005) |
|---|---|---|
| Introduce technology in context | | An overarching conception of what it means to teach a particular subject integrating technology in learning |
| Address worthwhile mathematics with appropriate pedagogy | | Knowledge of instructional strategies and representations for teaching particular topics with technology; Knowledge of curriculum and curriculum materials that integrate technology with learning in the subject area |
| Take advantage of technology | Technologies should enable students to do what they could not do without them. | |
| Connect mathematics topics | | |
| Incorporate multiple representations | Tools should facilitate the creation of sharable, modifiable, transportable models of mathematical and scientific concepts. | Knowledge of instructional strategies and **representations** for teaching particular topics with technology; |

*Figure 3*. Comparison of the goals of mathematics teacher education programs.

## Research Implications

This literature review has focused on six areas: 1) the significance of technology in mathematics education; 2) available technology tools for mathematical learning and the ways of classifying these tools; 3) teachers' evaluation of technology tools for mathematical learning; 4) appropriate uses of technology in mathematics education; 5) teachers' roles for technology; and 6) the development of identity of pre-service mathematics teachers. The review of the literature suggests that numerous factors influence the way in which pre-service teachers evaluate technology tools for mathematical learning. However, there is insufficient research to determine what those factors are, and how pre-service teachers utilize their evaluations of technology tools when planning for instruction. The result of this review highlights the fact that research was necessary to answer the research questions which guided this current research project.

# 3. METHODS

## Research Design

A qualitative research methodology was chosen for this study because "qualitative research…is best suited for research problems in which you do not know the variables and need to explore. The literature might yield little information about the phenomenon of study and you need to learn more from participants through exploration" (Creswell, 2005, p. 45). Previous researchers (Goos, Galbraith, Renshaw, & Geiger, 2003; 2000) have identified four roles for technology with respect to teachers: technology as master, technology as servant, technology as partner, and technology as extension of self. However, as previously noted, these roles were identified among secondary mathematics teachers who had been in the classroom for at least three years. Thus, this study specifically examined those roles in light of pre-service elementary teachers planning for mathematics instruction. In addition, a previous review of the literature found very few studies which were focused on pre-service elementary mathematics teachers' criteria for evaluating technology tools. Thus, this was designed to answer the previously identified research questions through a qualitative approach. The design included the use of a survey, a thought-revealing activity, lesson plans, videotaped class sessions, interviews, and case studies.

## Participants and Setting

Participants for this research study were recruited from two sections of the course: Elementary Math Methods, at a public university in the Mid-Atlantic Region, during the Fall, 2008 semester. These participants were enrolled in the graduate teacher licensure program. The program prepares elementary teachers who completed their bachelor's degree in a non-education field. The participants' fieldwork experiences ranged from kindergarten through grade 6. Each participant was assigned to a local public elementary school for the entire fall semester. Participants enrolled in Section 1 were assigned to a Professional Development School (PDS). Four days per week, for the entire semester, participants were immersed in one classroom for the full school day. One day per week they attended various subject-matter methods courses at the university. Participants enrolled in Section 3 were assigned to a Partner School (PS), where they were required to complete 15 hours of fieldwork throughout the semester. They also attended one or two methods courses at the university on a weekly basis.

The total number of participants for both sections was 35 pre-service teachers. Of these 35 participants, most (n=31) were female. The ages of the participants ranged from early 20s to late 40s/early 50s. Most of the participants were Caucasian. Their bachelor's degrees were typically business management, liberal arts, and other fields outside of education.

## Instruments

Three instruments were administered to and collected from the participants. The first instrument, Pre-Service Elementary Mathematics Teachers' Self-Reported Content

Knowledge and Technology Preparation Survey, was administered to participants at the end of the semester. See Appendix A for a copy of this instrument. The survey was divided into five parts. The first part asked teachers to rate their knowledge and understanding of fifteen mathematical topics found in the elementary curriculum. The second part asked teachers to rate their level of preparation to teach the same fifteen topics using technology. The third part asked teachers to explain which of those fifteen topics they feel most and least prepared to teach with technology. The fourth part asked teachers to identify various personal uses and experiences with technology, other than for academic purposes. The fifth part asked teachers to identify their mathematics coursework so far, as well as their fieldwork assignment (by grade level).

The second instrument, Planning for Instruction with Technology Reflection Document, was used by the participants as they wrote their lesson plan with technology integration. See Appendix B for a copy of this instrument. The instrument is a type of thought-revealing activity, which requires participants to deliberately reflect upon the choices they make while planning for instruction. The instrument required participants to report the objective of the lesson and rationale for this objective, the technology tool they selected and why they selected it, evaluation of the technology tool (which includes identifying criteria for evaluation, rationale for including these criteria, and evaluation based on each criterion), benefits and limitations of the technology tool (as perceived by the participant), representations afforded by the technology tool, how the tool will be utilized (demonstration, student exploration, etc.), and how class discussions and activities (led by the course instructor) influenced the design of the lesson plan.

The third instrument, Lesson Plan Format, is a standard lesson plan format used by pre-service elementary teachers at the university when planning for mathematics lessons. (See Appendix C for a copy of this instrument.) The major components of the lesson plan format include: lesson objective, materials for learning activities, procedures for learning activities, assessment, and differentiation.

All three of these instruments were collected from the participants electronically. Two additional instruments were used to collect data: videotapes of class sessions of the methods courses (which focused on the use technology and developing lesson plans with technology), and an interview protocol. The interview protocol included questions which required participants to reflect upon their responses on the first, second, and third instruments, as previously described. (See Appendix D for the interview protocol.)

## Procedures

During the fall semester, the pre-service teachers enrolled in the PDS methods course met bi-weekly, and the pre-service teachers enrolled in the PS methods course met weekly. They also worked with a cooperating teacher at a local public elementary school to complete their fieldwork experiences. The pre-service teachers were required to write, teach, and reflect upon three lesson plans during the course of the semester. The last of these three lesson plans required integration of technology.

During the semester, participants were introduced to various virtual manipulatives, such as those found at the National Council of Teachers of Mathematics (NCTM) Illuminations website, and the National Library of Virtual Manipulatives (NLVM) website, as well as other technology tools, which include applets, Smart

Boards®, calculators, and spreadsheets. During class sessions, the course instructor, asked the pre-service teachers to consider the benefits and constraints of each technology tool within the context of the standard or objective in question.

As a means of introducing the second instrument, Planning for Instruction with Technology Reflection Document (Appendix B), the instructor and researcher co-designed a mathematics lesson plan (Appendix E) using a virtual geoboard, a tool not commonly used by these particular pre-service teachers. During a class session in each section of the methods course (which was videotaped), participants discussed the lesson plan with the instructor and responded, as a whole-class, to the questions on the instrument. This activity was selected for several reasons. First, the researcher wanted to ensure understanding of the questions on the instrument prior to participant use. Second, the researcher wanted to ensure thoroughness of responses to the questions on the instrument. Third, the researcher wanted to refine the instrument for future use and research. After this class session, the researcher made notes for improvement for future use and research.

This particular activity was designed in light of the research discussed in Chapter 2. Because research has shown that pre-service teachers who consider the following are better prepared to teach with technology, this activity included:

- identifying criteria for evaluating technology tools
- identifying affordances and limitations of technology tools
- aligning a lesson plan which integrates technology to curriculum standards.

In addition, the instructor engaged pre-service teachers in identifying certain content and instructional features of the technology tool which should be emphasized. These features included:

- multiple and linked representations
- immediate feedback for students
- cognitive and mathematical fidelity of the technology tool.

Zbiek, Heid, Blume, and Dick (2007) define cognitive fidelity of a technology tool as "the degree to which the computer's method of solution resembles a person's method of solution" (p. 1176). They define the mathematical fidelity of a technology tool as the degree to which a "technology-generated external representation" is "faithful to the underlying mathematical properties of that object" (p. 1174). Throughout this class activity, pre-service teachers attended to the specific features of the technology tool in question. In particular, the researcher and instructor attended to the mathematics content of the lesson, and they assisted pre-service teachers as they unpacked the mathematics knowledge needed to teach the lesson using technology. Note that the development of this in-class activity mirrored the guidelines set forth by Garofalo, Drier, Harper, Timmerman, and Shockey (2000):

- Introduce technology in context
- Address worthwhile mathematics with appropriate pedagogy
- Take advantage of technology
- Connect mathematics topics
- Incorporate multiple representations (p. 67).

The instructor emphasized these five guidelines during the in-class activity.

Toward the end of the semester, as participants were planning their technology lesson, they responded to the questions on the second instrument, Planning for Instruction with Technology Reflection Document (Appendix B), and completed the Lesson Plan Format (Appendix C). These two instruments were sent by the pre-service teachers to the instructor and researcher electronically after teaching the technology lesson. When planning for instruction, the participants were allowed to use any of the technology tools discussed in class. These typically included virtual manipulatives, other tools found on math websites, spreadsheets, four-function calculators, and Smart Boards®.

During the last half of the semester, participants were asked to respond to the electronic survey, Pre-Service Elementary Mathematics Teachers' Self-Reported Content Knowledge and Technology Preparation (Appendix A). In addition, pre-service elementary teachers enrolled in Section 2 (taught by a different instructor than Sections 1 and 3) were asked to respond to the survey. The results of this survey were initially used as a point of comparison during the data analysis, since these pre-service elementary teachers were not engaged in the other activities as described in this chapter. The researcher obtained a copy of the course syllabus for Section 2, and he engaged in conversation with the instructor to discuss her uses of technology throughout the methods course. At the conclusion of the study, the researcher determined that the number of responses from each of the three groups of participants (Sections 1 and 3, which were part of the present study, and Section 2, the point of comparison) were not sufficient to make any meaningful comparisons among the groups of participants. Section 1 included

21 participants, and only 10 participants responded to the survey. Section 2 included 16 participants, and 12 participants responded to the survey. Section 3 included 14 participants, and 11 participants responded to the survey. Thus, the researcher did not include the results of the survey administered to Section 2 in the present data analysis.

## Data Sources

Data sources included the three instruments described above, namely Planning for Instruction with Technology Reflection Document (Appendix B), Lesson Plan Format (Appendix C), and Pre-Service Elementary Mathematics Teachers' Self-Reported Content Knowledge and Technology Preparation Survey (Appendix A), as well as videotaped class sessions taught by the instructor (as previously described). Once the three instruments had been collected, and data analysis had begun, the researcher also interviewed participants to explain, in further detail, the responses on their instruments. These interviews were done electronically, by using a chat feature, such as the one found on Blackboard. Electronic interviews were selected for two reasons: ease of scheduling, and the ability to record the entire text of the interview in electronic form. One limitation of electronic interviews is the potential for misinterpreting responses from the participants. The researcher was cognizant of this limitation and was sure to ask for clarification as necessary while conducting the electronic interviews. The electronic interviews were followed by face-to-face and/or phone interviews as necessary, because the responses to the electronic interviews may have been brief or limited. Several requests for interviews were emailed to the participants. Initially, seven participants indicated their willingness to participate in the interviews. However, after several requests, only two participants actually committed to an interview. One of these participants, who is highlighted in Chapter 5, gave thorough and complete answers to the interview questions, so she was selected (over the other participant, who gave very brief and limited answers) for the case study.

Table 1 notes which data sources were used to answer the previously identified research questions. It is important to note that the Reflection Document was the only data source used to help answer all of the research questions (for the entire group of participants) in the present data study.

Table 1.

*Research Questions and Data Sources*

| Research Question | Instrument: Survey | Instrument: Planning for Instruction with Technology Reflection Document | Instrument: Lesson Plan Format | Interview Protocol (Selected Participant for Case Study) |
|---|---|---|---|---|
| RQ 1 | | X | X | X |
| RQ 2 | X | X | X | X |
| RQ 3a | | X | | X |
| RQ 3b | | X | | X |

## Data Analysis Procedures

Data collected from the three instruments, Pre-Service Elementary Mathematics Teachers' Self-Reported Content Knowledge & Technology Preparation Survey, Planning for Instruction with Technology Reflection Document, and Lesson Plan Format, as well as the interviews, were analyzed to answer the research questions, as noted below.

*Research Questions 1 and 2:* 1) What roles exist between pre-service elementary teachers and the technology tools they choose to integrate in their mathematics lesson plans? 2) How do various internal factors (which include personal beliefs, as well as prior experiences with technology) and external factors (which include curriculum goals, cooperating teachers, and availability of technology) influence these roles (which may include master, servant, or partner, as well as others) observed between the pre-service elementary teachers and the technology tools?

The theoretical framework of Goos, Galbraith, Renshaw, and Geiger (2000) was *initially* used to characterize the interaction between the pre-service teacher and the technology. In their research, Goos, Galbraith, Renshaw and Geiger identified four roles for technology: technology as master, technology as servant, technology as partner, and technology as extension of self. Using the examples provided by the authors for each of these four roles, responses to two instruments were analyzed. These two instruments, Planning for Instruction with Technology and Lesson Plan Format, were completed by the participants to determine which role for technology best describes the interaction (if any) between the pre-service teacher and the technology.

Each of the categories has common characteristics which aided the assignment of a particular teacher to technology as master, technology as servant, and technology as partner. A teacher who views technology as master would evaluate a technology tool such that he or she uses or identifies only those features which he or she is knowledgeable. For example, a teacher might not use a technology tool because he or she does not understand how to use the tool and makes no effort to learn how to do so. A teacher who views technology as servant would evaluate a technology tool such that he or she uses the technology because he or she is familiar with it, but the technology is in line with his or her teaching methods. For example, a teacher might use a technology tool because it can be used to explore a mathematical concept, but that teacher does not identify any ways of modifying the activity or extending student learning beyond the affordances of the technology tool. A teacher who views technology as partner extends the potential of the technology tool and makes suggestions for advancing the technology tool beyond its capabilities. For example, a teacher might recommend a technology tool and suggest ways students could use the tool beyond the specific instructions provided by the technology tool. In this third role, the teacher places more of the responsibility for learning on the student, and he or she does not need to maintain complete control of the activity.

A rubric for classifying each of the participants as a particular role was developed. Figure 4 shows the three pre-existing roles, Master, Servant, and Partner, as well as the characteristics which should be found for each of these roles. The intermediate roles, Master-Servant, and Servant-Partner, are also included in the rubric.

| Role | Knowledge of Technology | Use of Technology | Actual Lesson vs. "Ideal" Lesson |
|---|---|---|---|
| Master | Limited knowledge of technology tools. Expresses an unwillingness to search for or figure out technology tools. Identifies or emphasizes "problems" with technology. | Technology may be used only AFTER physical manipulatives or other means are used with students. Views technology as "taking away" from valuable instruction time. | Would not make any changes.<br>OR<br>If changes are suggested, they include a removal of the technology altogether. |
| Master-Servant | Focused on the limitations | BUT AT THE SAME TIME | Recognizes possible uses of technology. |
| Servant | Aware of some of the limitations of the technology but doesn't necessarily work to overcome those limitations. However, still expresses a willingness and interest in using technology. Knowledge of the various technology tools is limited to those introduced in the methods course. | Uses technology as a substitute for something that can be done by hand or via a physical manipulative. | Would keep the technology tool the same, but perhaps make minor changes to the lesson plan. |
| Servant-Partner | Concerned about giving up control | BUT AT THE SAME TIME | Wants to encourage student exploration. |
| Partner | Has explored various technology tools on his or her own. Selects the technology tool which will best support student learning and takes into account the objective of the lesson. Takes advantage of the affordances within the tools to enhance math learning. Works to overcome limitations. | Uses technology alongside physical manipulatives to promote conceptual understanding. Students use technology to create, pose, and solve their own problems and those of classmates. | Thoughtfully considers what went well with lesson and focuses on student learning via the use of technology. Offers suggestions on how to make lesson better for the future. Willing to consider alternative technology to support student learning. |

*Figure 4*. Rubric for classifying roles.

In the rubric, the second and third columns correspond to multiple questions posed on the reflection document, as well as comments made on the participants' lesson plans. The final column, entitled Actual Lesson vs. "Ideal" Lesson, corresponds to a question posed to the participants on the reflection document: "If you didn't have the other influencing factors listed in Part C, what would you have done differently in your lesson plan? Why? Would you change the technology tool, or would you use the same one?"

Additional roles for technology emerged from an analysis of the data. The roles established by the literature and discussed in this chapter were not sufficient for categorizing the participants in the present study. These roles are identified and discussed in greater detail in Chapter 4.

Simple counts of each of the categories of roles were calculated (both by section and for the entire group of participants), and one participant per newly identified role was selected for case studies. The case study was written in narrative form, drawing from the responses on all three instruments, as well as from the interview data. As Goos, Galbraith, Renshaw, and Geiger (2000) note, the fourth role, technology as extension of self, is rarely observed.

Data collected from the three instruments (Planning for Instruction with Technology Reflection Document, Lesson Plan Format, and the Pre-Service Elementary Mathematics Teachers' Content Knowledge & Technology Preparation Survey) were used to address the various factors which influence these roles, namely internal (personal beliefs, prior experiences with technology) and external (curriculum goals, cooperating teachers, and availability of technology). Patterns among the five factors from the data analysis emerged and were reported. For example, the Likert-type responses to the Pre-Service Elementary Mathematics Teachers' Content Knowledge & Technology Preparation Survey were analyzed using simple statistical summaries, namely percentages and means. Specifically, the researcher was interested in exploring how teacher beliefs and content knowledge influenced pre-service teachers' use of technology in their lesson plans. The responses to the open-ended questions on the survey were read and analyzed.

*Research Question 3a:* When planning for instruction, what criteria do pre-service elementary teachers use to integrate technology tools for mathematical learning?

After the data were collected, each of the three criteria identified by each participant was coded using substantive categories, in order to stay close to the original data and words of the participants (Maxwell, 2005). Next, these substantive categories were grouped according to the theoretical categories established by Battey, Kafai, and Franke (2005), which include: software features, mathematics, learning, and motivation. In doing so, each substantive category was then placed under one of these four theoretical categories. See Table 2 for examples of the four theoretical categories and subsequent potential substantive codes and operational definitions, as identified by Battey, Kafai, and Franke (2005).

Table 2.

*Theoretical Categories, Potential Substantive Codes, and Operational Definitions*

| Codes | Operational Definitions |
|---|---|
| Software Features | |
| Clarity | Clarity of directions to the user |
| Visual | Clear visual presentation |
| Technology | Ease of technology use |
| Purpose | Purpose of tool needs to be clear |
| Feedback | Feedback provided by tool for the user |
| Mathematics | |
| General | General mathematics comments (e.g. meets a Standard) |
| Specific | Specific comments about mathematics (e.g. clarity of explanation of a concept) |
| Learning | |
| General | General comments about learning (e.g. age appropriate) |
| Specific | Specific comments about learning (e.g. allows for differentiation within a specific concept) |
| Motivation | |
| Fun | Tool needs to be fun |
| Like | Comments on whether they like the tool or not |

Battey, Kafai, and Franke (2005) initially developed these theoretical categories, substantive codes, and operational definitions from rational number software evaluations. Specifically, teachers evaluated games. Thus, in the previous table, references to games have been replaced with references to tools. Similarly, any specific references to games have been removed from the list of substantive codes. Other categories were established as the data was analyzed, since participants used technology tools other than games. And, in fact, while the categories did not change during the data analysis, other substantive codes and operational definitions were identified, and some were removed. A complete list of these substantive codes and operational definitions can be found in Table 9.

To ensure accurate coding of the criteria, both the criteria and rationale for the criteria were analyzed to determine the theoretical code assigned to that criteria. In the case of Learning versus Mathematics, there was potential for a criterion to be assigned to both, depending upon the rationale given by the participant. However, the researcher established a protocol for distinguishing between the two. For example, for Mathematics to be assigned, mathematics content or objectives had to be specifically mentioned by the participant. If mathematics was not specifically mentioned, Learning was the code assigned to that criterion. Also, care was taken to distinguish between Software Features and Motivation, because, once again, there was potential for a criterion to be assigned to both. In order to distinguish between the two, the researcher used the rationales for each criterion to determine which code was more appropriate. No criterion was assigned two theoretical codes, in keeping with the coding system developed by Battey, Kafai, and Franke (2005).

Next, simple frequency counts of each of the theoretical codes were calculated, to help identify patterns (Glesne, 2005). These counts were also reported as percentages, which were calculated as the ratio of number of times criteria are identified as compared to the total number of criteria identified. Finally, the four theoretical codes were divided into two major organizational categories: Content & Instruction (which includes Mathematics and Learning), and Surface Features (which includes Motivation and Software Features.) The proportion of total criteria for each of these two major organizational categories was then reported.

*Research Question 3b:* When planning for instruction, what perceived affordances and limitations do pre-service elementary teachers identify with respect to technology tools for mathematical learning?

Similar to research question 3a, responses to the instrument, Planning for Instruction with Technology Reflection Document, were analyzed by specifically looking at the affordances and limitations identified by the pre-service teachers. Substantive categories were once again used to code each of the participants' responses. Next, the researcher used these substantive categories to develop themes according to the codes. The researcher noted that the affordances and limitations identified by the participants primarily fell under one of four theoretical categories: Software Features, Motivation, Learning, and Mathematics. Thus, he used the coding scheme from research question 3a to classify the responses for the present research question. In addition, several other categories emerged from the data analysis. These categories are identified in the discussion of research question 3b. Operational definitions were also written to accompany these new theoretical categories.

# 4. RESULTS

This study used a qualitative approach to the data collection and the subsequent data analysis. The qualitative data presented in this chapter include the results of the electronic surveys, lesson plans, and reflection documents which were collected during the study. Tables and figures are presented to offer summary information about the participants, as well as to offer the reader descriptive information about the study. This chapter begins with the results of the first research question, following with results of the second research question and finally the results of the third research question (which includes two sub-questions). Note the following abbreviations have been used in tables, figures, and descriptive text:

- PDS refers to participants in Math Methods section 1, who were placed within a Professional Development School;
- PS refers to participants in Math Methods section 3, who were placed within a Partner School;
- PST refers to a Pre-Service Teacher, also known as a participant in the present study; and
- CT refers to a Cooperating Teacher, also known as the fieldwork placement site teacher.

If a number follows PDS- or PS-1, that number indicates the participant's unique identification code.

## Research Question One

The first research question was: What roles exist between pre-service elementary teachers and the technology tools they choose to integrate in their mathematics lesson plans? To answer this question, the researcher analyzed two documents from each of the participants: Planning for Instruction with Technology Reflection Document, and the Lesson Plan Format. Both documents were collected at the end of the semester in which participants were enrolled in their mathematics methods course. Participants were required to write and teach at least one lesson plan which integrated technology, and most participants chose to do so for their third (last) lesson plan, which was due at the end of the semester.

Document analyses of both of these instruments were performed to answer this research question. The researcher initially used the four roles established by the literature (Goos, Galbraith, Renshaw, & Geiger, 2003; 2000): technology as master, technology as servant, technology as partner, and technology as extension of self. After thorough document analyses, these roles were insufficient for answering the research question as it related to the participants in the present study. Seven roles emerged from the document analyses, and these roles are identified in Figure 1. Note that the original roles, as established in the literature, are *Master* and *Servant*, and are noted in bold print. The researcher chose a staircase to represent the progression of the roles identified in the present study. *Partner*, a role found in the literature, is included in the staircase, even though it was not found in the present study.

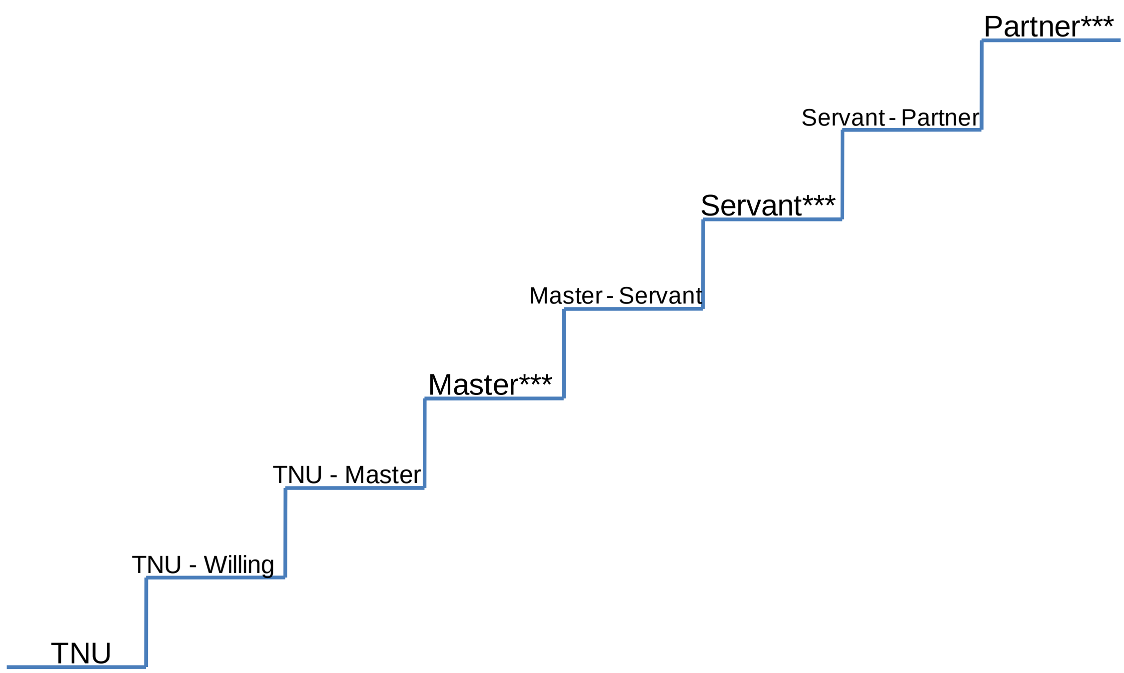



*Figure 5*. Roles from the present study. ***Note: In the item depicted, Master, Servant, and Partner are roles which have been previously identified by the literature (Goos, Galbraith, Renshaw, & Geiger, 2003; 2000). TNU, TNU-Willing, TNU-Master, Master-Servant, and Servant-Partner are all roles which emerged from the present study.

Three Technology Not Used roles were established in the present study: TNU, TNU-Willing, and TNU-Master. TNU indicates the participant did not use technology in the lesson plan submitted, and no further information was offered (i.e., the participant did not express a willingness or opinion about technology use.) TNU-Willing indicates the participant was not able to integrate technology, primarily because the cooperating teacher (CT) or curriculum did not allow it, but they were willing to integrate technology if possible. TNU-Master indicates the participant did not integrate technology, but their reflection indicated a possible manner of technology integration which best matches the role of Master. In the case of the Master role, technology use is limited because of the comfort level or familiarity of the instructor. Master-Servant indicates the participant demonstrated beliefs and actions characteristic of both Master and Servant roles. The participant was not firmly located within either role. In the case of the Servant role, technology is not necessarily used for concept exploration or development, nor is it used in a creative manner to change the type of activity students would typically complete in the instructor's course. Servant-Partner indicates the participant demonstrated beliefs and actions characteristic of both Servant and Partner roles. The participant was not firmly located within either role. The present study did not identify Partner or Extension of Self roles among the participants.

Figure 5 shows the progression of the roles from TNU all the way up to Servant-Partner. These roles are a progression rather than a simple linear pattern. Particularly in the Master-Servant and Servant-Partner roles, there is tension between the steps immediately preceding and immediately following that particular role. The participant was not firmly located in either Master or Servant, or Servant or Partner. Rather, they exhibited characteristics which could be found in both classifications. This is not a complete staircase. Rather, other steps could be added through further research.

*Technology Tools Used by the Participants*

To determine if there was a relationship between the type of tool and the role of the PST, the tool types were recorded during the document analyses. Tables 3 (PDS) and 4 (PS) list the types of technology tools used by the participants, along with their identification numbers and the roles between the teachers and the technology they used. Note that the participants are listed in order of the progression from TNU through the highest possible role.

Table 3.

*Technology Tools Used: PDS*

| Role | Technology Used | ID |
|---|---|---|
| TNU | *Technology not used* | PDS-5, 12 |
| TNU-Willing | *Technology not used* | PDS-16 |
| TNU-Master | *Technology not used* | PDS-7 |
| Master | Smart Board® – Slides | PDS-2 |
| Master | Smart Board® – Display | PDS-9, 19, 20, 21 |
| Master | NLVM - Multiplication | PDS-18 |
| Master | Illuminations | PDS-11 |
| Master-Servant | Smart Board® – Display | PDS-6 |
| Servant | Smart Board® & Internet website math game | PDS-1 |
| Servant | NLVM – Addition and subtraction with decimals | PDS-4 |
| Servant | NLVM & Smart Board® | PDS-10 |
| Servant | PowerPoint | PDS-13 |
| Servant | Smart Board® – Fraction pie pieces | PDS-14 |
| Servant | Illuminations – Base 10 model | PDS-15 |
| Servant | Smart Board®/Illuminations – Fraction Game | PDS-17 |
| Servant-Partner | NLVM – Base Ten Blocks (subtraction) | PDS-8 |
| Servant-Partner | Smart Board® – Interactive dice | PDS-3 |

Table 4.

*Technology Tools Used: PS*

| Role | Technology Used | ID |
|---|---|---|
| TNU | *Technology not used* | PS-6 |
| TNU | *Technology not used* | PS-9 |
| Master | Cell phone | PS-10 |
| Master | Calculator | PS-5 |
| Master | NLVM - Internet game | PS-1 |
| Master | Internet site | PS-2 |
| Master | Bar graph applet (Illuminations) | PS-14 |
| Master | Smart Board® (Brainpop movie) & Internet (practice tool) | PS-11 |
| Master-Servant | Smart Board® & Website (Base 10 blocks) | PS-3 |
| Master-Servant | Smart Board® | PS-4 |
| Master-Servant | NLVM - Patterns & Smart Board® | PS-7 |
| Master-Servant | NLVM - Base 10 blocks | PS-13 |
| Servant | Website provided by textbook publisher | PS-12 |
| Servant-Partner | Illuminations Geometric Shape Tool | PS-8 |

As these tables demonstrate, the Smart Board® was the most popular choice of the participants (n=15 for both groups combined). This is especially true for the PDS (n=11). Since Smart Boards® were readily available in the classrooms and schools of the participants, this is not a surprising result.

While not a focus of this study, the researcher was interested in differences which potentially existed between the two groups (PDS and PS). Thus, for the tables in this chapter, the results are presented separately for each group, and then as a combined whole. As noted in the sections which follow, no significant differences were found between both groups. However, the data is presented in both forms in order to present the reader with accurate and complete information about the results.

*Participants: Professional Development Schools (PDS)*

There were 21 PDS PSTs in the elementary math methods course who participated in the present study. A summary of the roles which exist between the technology and these PST is noted in Table 5.

Table 5.

*Roles between PST and Technology: PDS*

| Role | Number (n=21) | Percent |
|---|---|---|
| TNU | 2 | 9.5% |
| TNU – Willing | 1 | 4.8% |
| TNU – Master | 1 | 4.8% |
| Master | 7 | 33.3% |
| Master-Servant | 1 | 4.8% |
| Servant | 7 | 33.3% |
| Servant-Partner | 2 | 9.5% |

As stated in Table 5, 2/3 of the PDS participants can be classified as Master or Servant, as defined in the literature. However, the remaining 1/3 of the PDS participants found themselves in roles not previously identified but established by the present study.

*Participants: Partner Schools (PS)*

There were 14 PS PSTs in the elementary math methods course who participated in the present study. A summary of the roles which exist between the technology and these PST is noted in Table 6.

Table 6.

*Roles between PST and Technology: PS*

| Role | Number (n=14) | Percent |
|---|---|---|
| TNU | 2 | 14.3% |
| TNU – Willing | 0 | 0% |
| TNU – Master | 0 | 0% |
| Master | 6 | 42.9% |
| Master-Servant | 4 | 28.6% |
| Servant | 1 | 7.1% |
| Servant-Partner | 1 | 7.1% |

The majority of the PS participants were located within the Master role (42.9%) and Master – Servant role (28.6%). Note that only 14.2% of the PS participants were located within the Servant or Servant-Partner roles. No PS participants were located within the TNU – Willing or TNU – Master roles.

Finally, the overall results combine the PDS and PS into one group. Table 7 presents the overall results of the roles between PST and technology.

Table 7.

*Roles between PST and Technology: PDS and PS Combined*

| Role | Number (n=35) | Percent |
|---|---|---|
| TNU | 4 | 11.4% |
| TNU – Willing | 1 | 2.9% |
| TNU – Master | 1 | 2.9% |
| Master | 11 | 37.1% |
| Master-Servant | 6 | 14.3% |
| Servant | 8 | 22.9% |
| Servant-Partner | 3 | 8.6% |

Even though the numbers of participants are relatively small, percents are used in Tables 5, 6, and 7 in order to make comparisons between groups (PDS and PS) and among the total group of participants. The *n* of each group is different, so percents are more appropriate as a means of comparison. The percents are not used to show statistically significant differences among the data.

*Descriptions of the Seven Roles: PDS and PS*

A description of each of the seven roles, with highlights from the lesson plans and reflection documents, is presented below.

*TNU*. Two PDS PSTs did not integrate technology into their lesson plans, and their comments were not sufficient to classify them in a TNU-Willing or a TNU-Master role. One of these PSTs (PDS-5) did not submit a reflection document. The other PST (PDS-12), who was placed in a fourth grade classroom, had this to say about her not using technology:

> I wasn't able to incorporate technology into my lesson because we follow *Math Investigations*. I did end up changing the *Math Investigations* lesson that I taught a little bit, but that's only because it was a review of what the children had already learned. I was not able to incorporate technology because of the restrictions of teaching *Math Investigations*.

Thus, this PST followed the curriculum (as well as the direction of the CT) when planning her lesson.

Two PS PSTs also did not integrate technology into their lesson plans. Neither of these participants submitted reflections, so the researcher could not further classify them as TNU-Willing or TNU-Master. No further information was given by the participants or the methods course instructor to determine the reason for the lack of technology integration.

*TNU – Willing*. One PDS PST was classified as the TNU-Willing role. She (PDS-16) was not able to use technology in her lesson, but in her reflection document, she indicated a willingness to do so. When asked about her "ideal" lesson, she replied:

> If I did not have to follow *Math Investigations*, I would have taken my students to the computer lab and taught a math lesson using the Smart Board®. There are so many more interesting ways I could have approached the lesson, but I have to follow the math curriculum.

Then, in her comments about what she had learned in the methods course, this PST stated,

> I learned a lot from observing the different ways we could integrate technology in class discussions but I have not had the chance to implement these tools. I feel like it is much more difficult using technology with such small children, especially in math because they are just beginning to form their understanding of many different math skills. However, if technology was more readily available to me, I would not have a problem doing so.

Thus, this PST expressed a willingness to use technology, but her comments were not sufficient to determine if it could be classified as another role, such as Master, Servant, or Partner.

No PS PSTs were classified as TNU – Willing.

*TNU – Master*. One PDS PST was classified as the TNU – Master role. This PST (PDS-7), placed in a third grade classroom, was required to teach measurement of liquid volume in U.S. Customary units for her lesson. She did not use technology, but her comments about technology are consistent with the Master role. When responding to the question about which technology was used in the lesson, this PST stated:

> There is little working technology in our classroom – the Smart Board® does not function – and my CT does not use it. I pushed to introduce as much manipulative work as I did during my SIT [Supported Independent Teaching] period, so I decided to limit this to manipulatives. I also decided that these children needed to see and use REAL cups, pints,

quarts, half-gallons and gallons (pouring dyed blue water, investigating non-potable items as being liquids we measure in these capacities as well) more than they needed to see “neat” images of liquid capacity on the Smart Board® so that it would not handicap them in this lesson to focus on the “real” containers and not use technology. I wanted to give them as much concrete experience as possible first, and Smart Board® technology would be a step away from concrete. In later lessons, continuing the learning with Smart Board® would have been great, however – a much better alternative than just going on to symbolic “worksheets.”

When reflecting upon what her “ideal” lesson might be, she stated:

> The ideal lesson for these children would have been hours and hours of work with liquid capacity at a concrete level. They desperately needed the exposure. Then I would have moved on to the Smart Board® for exploration at a pictorial level, because this would have offered so many possibilities for them to grasp the concepts at the pictorial stage. Instead, I used more primitive paper representations of capacity. Even though they were more primitive than the Smart Board®, they were a productive way to reinforce student understanding, and from one perspective they were preferable in that they were something the students were actually manipulating on their own to arrive at answers, and not something on a screen that they were manipulating in a less physical way (sliding fingers across the whiteboard to place images in certain spots, etc.

is in some ways more removed than the child working with their own hands with the paper representations.

This PST focused on the limitations of the technology, rather than considering the possible affordances provided by the Smart Board®.

No PS PSTs were classified as TNU – Master.

*Master*. Seven PDS PSTs were classified as having the Master role. PDS-2, who was assigned to a second grade classroom, exhibited characteristics of the Master role because of her limited knowledge and comfort level with technology. This PST created a Power Point for the Smart Board®. Individually, students came up to the Smart Board® to slice a pizza into different fractional amounts, such as one-half, one-quarter, and so on. When asked why she chose this form of technology, she responded by saying “I went on the virtual manipulatives website but I felt it was too hard for the second day of fractions.” The PST demonstrated concern about the complexity of one particular technology tool, and she even admitted in her reflection document that her knowledge of fractions was weak. When asked about the influence of her cooperating teacher, she responded, “She taught me how to work the Smart Board® so I could make my Power Point interactive and the students were able to write on it.” And finally, when this PST was asked to identify any other factors which influenced her selection of technology, she replied, “I was having computer problems the previous day so this just made me a little hesitant about the outcome of the lesson.” All of these statements, as well as others made in both the lesson plan and reflection documents, are consistent with the Master role.

Six PS PSTs were classified as the Master role. One of these participants (PS-10) used a cell phone with her class. The objective of the lesson was, “Given a cellular phone, students will be able to recognize numerals 0-9 and dial their ten digit phone number with 100% accuracy. However, this PST only had one cell phone available to students in the Kindergarten class, and the students used a paper model of a cell phone for the bulk of the lesson. When asked about her technology selection, this PST said, “I chose a technology tool that could be used in the classroom instead of having the students leave the room.” When asked about limitations or constraints of the selected technology tool, she noted, “Because the cell phone is small, it is not something you can hold up to show to the entire class. It is better used with a small group lesson.” Note how the teacher focused on the limitations of the technology, a characteristic found in the Master role. Further discussion with this participant would have revealed why she considered a cell phone to be a technology tool for mathematical learning.

*Master – Servant*. One PDS PST was classified as the Master-Servant role. He (PDS-6) exhibited characteristics consistent with both roles, but he could not be explicitly classified as one or the other. This PST, who was assigned to a fourth grade classroom, used a Smart Board® to engage students by placing fractions on a number line. Several comments on the reflection document indicated a Master role. For example, this PST stated:

> Whenever I use the Smart Board®, the computer that I try to use to hook up to it tends to freeze or fail….Also, if the computer HAD frozen during

> my preparation (as it often did for other lessons) then I would have had to do this activity on a regular white board.

He also stated that the reason he selected this tool was “the easy access to the Smart Board® and the students’ familiarity with it as an instructional tool.” He also indicated that he relied on his Cooperating Teacher to help him plan this particular lesson. However, this PST also made several comments consistent with the Servant role. For example, this PST stated, “Since we were comparing fractions, I knew that I wanted to use the number line model. Instead of doing it on a plain board, I decided to use the Smart Board® because I thought the students would be more engaged by getting a chance to interact with it.” These statements are consistent with the Servant role, where technology is used as a substitute for other media. In addition, when this PST reflected upon his lesson, he stated that “In fact, looking back now, it would have been a great idea to include pictures to help students SEE the differences between fractions as they placed them on the number line.” This PST was beginning to see the other possible uses of the technology, but he had not actually taken advantage of them during the lesson.

Four PS PSTs were classified as the Master-Servant role. For example, PS-3, who was assigned to a fourth grade classroom, used a Smart Board® and virtual base ten blocks to engage students in multiplication problems. He exhibited characteristics consistent with both roles, but he could not be explicitly classified as one or the other. For example, this PST noted, “Since I was not familiar with the Smart Board®, I did not know I had to place the eraser and pen back to the board so I could use the Smart Board® again. To compensate, [my CT] would click and drag the pieces for me on the computer and tell me to put the marker and eraser." Note this PST had limited knowledge of the technology tool and relied upon his cooperating teacher to help him use the technology. This indicates a Master role. At the same time, this PST also exhibited characteristics of the Servant role. For example, when questioned about his "ideal" lesson, this PST said, "I would have provided each student a manipulative during the lesson so they could connect the technology to the manipulatives in their hands. I would not change the technology tool because it was useful for the lesson."

*Servant*. Seven PDS PSTs were classified as the Servant role. One PST (PDS-4), who was assigned to a fourth grade classroom, used the National Library of Virtual Manipulatives addition and subtraction with decimals tool. When asked why she selected this tool, this PST responded, "It helped to review the concept of regrouping which these students need anyway." Notice the PST focused on reviewing the concept, rather than students developing the conceptual understanding of addition and subtraction with decimals (which would be more consistent with the Partner role.) When discussing her actual lesson, the PST stated, "I used whole class instruction to show the students the website on regrouping. After they got the concept I gave them manipulatives and had them compute the problems with manipulatives while I used the website." These statements indicate teacher control of the technology, as well as using technology as a substitute for physical manipulatives, both of which are consistent with the Servant role.

One PS PST (PS-12) was classified as the Servant role. Assigned to a fifth grade classroom, this PST created a lesson in which students reviewed divisibility rules and practiced division with one- and two-digit divisors. She used a website, provided by the textbook publisher, to engage students in review and practice. Since students were using technology to perform computations which could have been done by hand, this PST's classification is consistent with the Servant role.

*Servant – Partner*. Two PDS PSTs were classified as the Servant-Partner role. These participants exhibited characteristics of both the Servant role, as well as the Partner role. For example, PDS-3, a fourth grade teacher, used interactive dice on the Smart Board®. When asked about her choice of technology, this PST replied, "The lesson I created included interactive dice to roll to create improper fractions. It also included fraction piece manipulatives that students interacted with to create improper fractions and mixed numbers." Both of these uses of technology are consistent with the Servant role, in which teachers use technology as a substitute for another medium, such as paper and pencil or physical manipulatives. This PST continued by saying:

> I selected this tool because it allowed students to see and put together visual representations of improper fractions, and how they were the same as the corresponding mixed number…..It was interactive, and had a strong visual component necessary for most students to understand the concepts of improper fractions and their relationship to mixed numbers.

These last two statements are characteristic of the Partner role, in that technology is used to engage and extend student learning. Rather than "receiving" information, the students are using technology to build their own knowledge of a particular mathematical concept.

One PS PST was classified as the Servant-Partner role. This PST (PS-8) was assigned to a third grade classroom. For her lesson, she used the NCTM Illuminations

Geometric Shape tool. Her lesson and reflection exhibited features of both Servant and Partner roles. For example, when asked about her ideal lesson, she replied:

> If I had had a projector and screen, I would have demonstrated how to use the tool on the computer instead of giving them [the students] instructions. I would keep the same technology tool because the students enjoyed it and it helped the students gain a better understanding of geometric shapes.

Note that this statement can be found in both roles. During the actual lesson, the teacher was in control of the technology, which is consistent with the Servant role. At the same time, however, this PST was interested in student exploration and concept development. This is consistent with the Partner role. Her lesson plan and reflection documents include comments consistent with both the Servant and Partner roles.

## Research Question Two

The second research question was: How do various internal factors (which include personal beliefs, as well as prior experiences with technology) and external factors (which include curriculum goals, cooperating teachers, and availability of technology) influence these roles (which may include master, servant, or partner, as well as others) observed between the pre-service elementary teachers and the technology tools? To answer this question, responses to participants' items on the "Planning for Instruction with Technology Reflection Document" and the "Pre-Service Elementary Mathematics Teachers' Self-Reported Content Knowledge & Technology Preparation Survey" were analyzed.. The results of this question are discussed in five sections below. Each section includes one of the five factors identified by the research question.

*Personal Beliefs*

PST personal beliefs about technology were difficult to identify from the data collected. Explicit statements of personal belief were rare in the data set. The researcher found that stated beliefs about technology had more to do with student goals than PST personal beliefs. For a more detailed analysis of beliefs about the goals of technology for students, see the results of Research Questions 3a and 3b.

*Prior Experiences with Technology*

Participants were asked to respond to a survey question which addressed their prior experiences with technology, outside of mathematics education. Specifically, participants were asked to identify how often they use various technology applications in their daily lives (other than academic or employment uses.) The results for the PDS & PS Combined Groups (Table 8) follow. Discussion follows the table. The table show the percent of responses per category.

Table 8.

*PDS and PS Uses of Technology in Everyday Life (Combined Results) (n=21)*

| Technology Application | Multiple Times Each Day | Once a Day | Several Times per Week | Rarely | Never |
|---|---|---|---|---|---|
| Instant Messaging | 20% | 5% | 15% | 25% | 35% |
| Text Messaging | 75% | 5% | 5% | 15% | 0% |
| Social networks | 40% | 15% | 10% | 15% | 20% |
| Blackberry, PDA, etc. | 15% | 0% | 0% | 10% | 75% |
| Email | 90% | 10% | 0% | 0% | 0% |
| Word processing | 50% | 20% | 15% | 10% | 5% |

Overall, the participants in both groups had experiences with multiple forms of technology. Email (90%), text messaging (75%), and word processing (50%) were the technology tools used multiple times a day by participants. Thus, participants were experienced with technology and were not hindered by a lack of technology in their personal and daily lives.

*Curriculum Goals*

The researcher was interested in identifying a potential correspondence of the objectives of the lessons taught by the PST to the roles discussed in Research Question 1. In other words: Do PSTs at a higher level (i.e., Servant or Servant-Partner), exhibit characteristics different from those at a lower level (i.e., TNU-Master, Master, or Master-Servant)? Specifically, do those at a higher level choose the objective before choosing the technology, and do those at the lower level choose the technology before the objective? Thus, the researcher analyzed the reflection documents based upon the role played by the lesson objectives.

For the PDS PSTs, of those who can be classified as Master, one PST stated that the objective did not play any role in choosing the technology, two PSTs stated that the objective was selected before the technology, and four PSTs did not specifically make a statement about the role of the objective in the lesson and the technology choice. For those who could be classified as Servant, five PSTs stated that the objective was selected before the technology, and 1 PST stated that the technology was selected first. The remaining participants fell under the other established roles.

For the PS PSTs, of those who can be classified as Master, three PST stated that the objective was selected before the technology, and three PSTs did not specifically make a statement about the role of the objective in the lesson and the technology choice. For those who could be classified as Master-Servant, three PSTs stated that the objective was selected before the technology, and one PST stated that the technology was selected first. The remaining participants fell under the other established roles.

Of the PDS PSTs who did not use technology (TNU and TNU-Willing), two of the participants indicated that their reason for not doing so was the curriculum itself. Both of these participants taught early elementary grade levels (K-2) and were using *Math Investigations*. Both participants indicated in their reflections that the curriculum does not allow for the use of technology, and therefore they were not able to integrate technology into their lesson plans.

The results are somewhat inconclusive, because the numbers are so small and because the apparent correspondence between a PST role classification and the objectives is not very strong. However, it appears as if those toward the higher end of the hierarchy of roles (Master-Servant, Servant, and Servant-Partner) tended to choose the objective first and used technology to support the lesson objectives. And, it appears as if those toward the lower end of the hierarchy (in particular, Master), tended to give no explicit statement regarding the role of the objective.

*Cooperating Teachers*

The influence of Cooperating Teachers (CT) was varied among the participants. Was there an influence of CT on the roles previously identified in Research Question 1? To answer this question, the participants' reflections were coded according to the Cooperating Teacher influence. A matrix (see Figures 6 and 7) was designed to capture this potential influence. The left vertical column indicates the four possible roles (Master, Master-Servant, Servant, and Servant-Partner) for those participants who used technology. The top horizontal row indicates five possible influences by the CT (No influence, Teacher doesn't use technology or limited use, Teacher identified the technology or taught the PST how to use it, Teacher supportive of technology, and Strong Influence) as noted in their reflection documents. The results for the PDS (Figure 6) and PS (Figure 7) follow with discussion.

| Role | No Influence | Teacher doesn't use tech/limited use | Teacher identified tech or taught PST how to use it | Teacher supportive of technology use | Strong Influence |
|---|---|---|---|---|---|
| Master | 2 | 1 | 3 | 1 | 0 |
| Master-Servant | 0 | 1 | 0 | 0 | 0 |
| Servant | 2 | 2 | 1 | 1 | 0 |
| Servant-Partner | 1 | 0 | 0 | 0 | 1 |
| Total | 5 | 4 | 4 | 2 | 1 |

*Figure 6.* Matrix comparing roles and cooperating teacher (CT) influence: PDS.

| Role | No Influence | Teacher doesn't use tech/limited use | Teacher identified tech or taught PST how to use it | Teacher supportive of technology use | Strong Influence |
|---|---|---|---|---|---|
| Master | 4 | 0 | 0 | 1 | 1 |
| Master-Servant | 2 | 1 | 1 | 0 | 0 |
| Servant | 1 | 0 | 0 | 0 | 0 |
| Servant-Partner | 0 | 0 | 0 | 0 | 1 |
| Total | 7 | 1 | 1 | 1 | 2 |

*Figure 7.* Matrix comparing roles and cooperating teacher (CT) influence: PS.

An analysis of these matrices does not support a strong influence of Cooperating Teacher on the roles previously identified for the PST. For both groups (PDS and PS), Cooperating Teacher influence was widely varied depending upon the role between the PST and the technology (Master, Master-Servant, Servant, and Servant-Partner.) Therefore, Cooperating Teacher influence appeared to have no correspondence with PST roles with technology. That is not to say that the Cooperating Teachers had no influence upon the PST themselves. Rather, CT influence was not a factor for establishing the roles between PST and technology.

*Availability of Technology*

Technology access in the classrooms and schools of the PSTs had a wide range of possibilities. Responses to items on the Reflection Document included limited working technology in the building, sets of 3 or 4 classroom computers, Smart Boards® in each classroom, Smart Boards® available for "check out", class sets of laptops for "check out", and computer labs available for reservation. Those PSTs who indicated limited access to technology (i.e., computer lab not available for that particular day) also stated they still used technology and found ways to work around the limited technology available to them. After a careful document analysis, the various types of technology access (from little or none to plentiful) were distributed fairly equally among the various roles as discussed in Research Question 1. Thus, in the case of these PSTs, technology access did not appear to have an influence on roles between teachers and technology. As noted in Tables 3 and 4, however, Smart Boards® were used by the majority of the PSTs, and this could be explained by their ubiquitous nature in the classrooms and schools of the participants.

## Research Question Three

The third research question was: How do these roles influence the ways in which pre-service elementary teachers plan for mathematics instruction? This research question was supported by two sub-questions, which are addressed in the following sections. These sub-questions were:

a) When planning for instruction, what criteria do pre-service elementary teachers use to evaluate technology tools for mathematical learning?

b) When planning for instruction, what perceived affordances and limitations do pre-service elementary teachers identify with respect to technology tools for mathematical learning?

To answer these questions, participant responses to items on “Planning for Instruction with Technology Reflection Document” were analyzed Each of these research sub-questions is addressed in separate sections which follow.

### *Research Question 3a*

Participants were asked to respond to the following item on the Planning for Instruction with Technology Reflection Document: “What characteristics of the tool influenced your selection? (Note: You do not need to have five. You may have more, or less, depending upon your beliefs.)” Participants recorded their criteria in a table, as shown in Figure 8.

| **Criterion** | **Rationale for Inclusion of this Criterion** | **Evaluation of Technology Tool based on this Criterion** |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

*Figure 8*. Table to record criteria, rationale, and evaluation of technology tool.

A document analysis of the participants' responses to this item was then performed (Miles & Huberman, 1994). Initially, the theoretical categories, substantive codes, and operational definitions, as identified in Chapter 3 (see Table 2) were used. During the document analysis, further substantive codes, which fell under the four theoretical categories, were identified. Operational definitions for these new substantive codes were constructed. The revised coding schema is identified in Table 9.

Table 9.

*Coding Schema for RQ 3a: Theoretical Categories, Substantive Codes, and Operational Definitions*

| Codes | Operational Definitions |
|---|---|
| Software Features | |
| Clarity | Clarity of directions to the user |
| Visual | Clear visual presentation |
| Technology | Ease of technology use |
| Purpose | Purpose of tool needs to be clear |
| Feedback | Feedback provided by tool for the user |
| Security/Safety | Pop-ups not included, doesn’t link to inappropriate sites |
| Time | Time needed for set up or to understand usage |
| Mathematics | |
| Content | Comments about mathematics content (e.g. specific math concepts which can be explored via the tool) |
| Visual | Offers visual representations and/or reinforces concepts visually |
| Learning | |
| Student Use | Comments about how students use the tool (e.g. independent learning, centers) |

| | |
|---|---|
| Student Learning | Comments about student learning (e.g. allows for differentiation within a specific concept) |
| Motivation | |
| Affective | Comments about the tool being fun or students liking the tool |
| Student Interest | Comments about tools maintaining student interest |
| Engagement | Maintains student engagement |

Once the criteria had been coded, they were grouped according to the four theoretical categories: software features, motivation, mathematics, and learning. Simple counts of each of the criteria were noted, and the percentage of the total criteria identified was calculated. See Tables 10 and 11 for the results of the PDS participants and the PS participants, respectively. The researcher desired to initially analyze the separate results of each of the groups, thus the separate tables.

Table 10.

*PDS Criteria for Evaluating Technology Tools*

| Criterion | Total | Percent of Total |
|---|---|---|
| Software Features (SF) | 25 | 53.2% |
| Motivation (MO) | 14 | 29.8% |
| *Surface Features* | | *83%* |
| Learning (LE) | 2 | 4.3% |
| Mathematics (MA) | 6 | 12.8% |
| *Content & Instruction* | | *17%* |
| Total | 47 | 100% |

Table 11.

*PS Criteria for Evaluating Technology Tools*

| Criterion | Total | Percent of Total |
|---|---|---|
| Software Features (SF) | 16 | 51.6% |
| Motivation (MO) | 7 | 22.6% |
| *Surface Features* | | *74%* |
| Learning (LE) | 4 | 12.9% |
| Mathematics (MA) | 4 | 12.9% |
| *Content & Instruction* | | *26%* |
| Total | 31 | 100% |

When comparing both groups, it is evident that there were major similarities in the Software Features (PDS: 53.2%; PS: 51.6%) and Mathematics (PDS: 12.8%; PS: 12.9%). Further, there were similarities in Motivation (PDS: 29.8%; PS: 22.6%) and Learning (PDS: 4.3%; PS: 12.9%) between both groups. What is obvious is that Software Features accounted for over 50% of the criteria identified by both groups.

In keeping with the coding schema established by the literature (Battey et al., 2005), the researcher then grouped two theoretical categories to form an organizational category: Surface Features. Surface features include the two theoretical categories: Software Features and Motivation. The two other theoretical categories, Learning and

Mathematics, were grouped to form another organizational category: Content and Learning. These organizational categories, which have been established in the literature, were not altered in the present study. Tables 10 and 11 include the percentages of each of these two major categories, in italics, by group.

As Table 11 suggests, Surface Features was the primary concern of the participants in both groups. There is only a 9% difference between groups, and therefore these results are fairly similar.

Table 12 presents the overall results of this research question, with all criteria listed for the combined group of participants. Note the same codes are used for the combined group of participants.

Table 12.

*Combined Criteria Results for PDS and PS*

| Criterion | Total | Percent of Total |
|---|---|---|
| Software Features (SF) | 41 | 52.6% |
| Motivation (MO) | 21 | 26.9% |
| *Surface Features* | | *79.5%* |
| Learning (LE) | 6 | 7.7% |
| Mathematics (MA) | 10 | 12.8% |
| *Content & Instruction* | | *20.5%* |
| Total | 78 | 100% |

As can be noted from Table 12, the combined results are very similar to the results of each of the two groups (PDS and PS). As noted previously, Software Features was the criterion identified over 50% of the time. Motivation was the criterion identified over 25% of the time. Learning was identified approximately 8% of the time, and Mathematics was identified approximately 13% of the time across both groups. Ranked in order from most frequent to least, these four criteria are as follows: Software Features, Motivation, Mathematics, and Learning.

A review of Table 12 notes that 79% of the participants' responses dealt with Surface Features (which includes Software Features and Motivation.) 21% of the participants' responses dealt with Content and Instruction (which includes Learning and Mathematics). In summary, participants in this study were primarily concerned with software features and motivation, whereas they were marginally concerned with learning and mathematics.

*Research Question 3b*

Participants were asked to respond to the following two items on the Planning for Instruction with Technology Reflection Document: "What benefits or features do you recognize in this technology tool? What limitations or constraints do you recognize in this technology tool?" A document analysis of the participants' responses to this item was then conducted. Initially, the theoretical categories, substantive codes, and operational definitions previously identified for Research Question 3a and shown in Table 9, above, were used to answer this question. In addition to these substantive codes, three others were identified as a result of the document analysis. These three substantive codes, which do not find themselves in any of the four theoretical categories, are: access, none, and other. Access refers to students' ability to physically access the technology. None indicates the participant specifically stated there was no affordance or limitation with the technology tool. And other refers to a criterion which does not fit into any of the substantive codes. Simple counts of each of the criteria were noted, and the percentage of the total criteria identified was calculated. See tables 13 and 14 for the results of the PDS participants and the PS participants, respectively. As stated previously, the results are first displayed in separate tables as a means of presenting the data.

Table 13.

*PDS Self-Identified Affordances and Limitations of Technology*

| Category | Total | Percent of Total |
|---|---|---|
| Software Features (SF) | 27 | 51.9% |
| Motivation (MO) | 12 | 23.1% |
| Learning (LE) | 7 | 13.5% |
| Mathematics (MA) | 4 | 7.7% |
| None Identified (NO) | 2 | 3.8% |
| Total | 52 | 100% |

Table 14.

*PS Self-Identified Affordances and Limitations of Technology*

| Category | Total | Percent of Total |
|---|---|---|
| Software Features (SF) | 18 | 50.0% |
| Motivation (MO) | 4 | 11.1% |
| Learning (LE) | 5 | 13.9% |
| Mathematics (MA) | 5 | 13.9% |
| Access (AC) | 2 | 5.6% |
| Other | 2 | 5.6% |
| Total | 36 | 100% |

Even though the numbers of participants are relatively small, percents are used in Tables 13, 14, and 15 in order to make comparisons between groups (PDS and PS) and among the total group of participants. The *n* of each group is different, so percents are more appropriate as a means of comparison. The percents are not used to show statistically significant differences among the data.

When comparing both groups, it is evident that there were major similarities in the Software Features (PDS: 51.9%; PS: 50.0%) and Learning (PDS: 13.5%; PS: 13.9%). Further, there were similarities in Mathematics (PDS: 7.7%; PS: 13.9%). Motivation saw a slightly greater difference between the groups (PDS: 23.1%; PS: 11.1%) .

Next, overall results of this research question were documented by an analysis, of the affordances and limitations as one combined group of participants. The results are shown in Table 15.

Table 15.

*Combined Results for PDS and PS Self-Identified Affordances and Limitations of Technology*

| Category | Total | Percent of Total |
|---|---|---|
| Software Features (SF) | 45 | 51.1% |
| Motivation (MO) | 16 | 18.2% |
| Learning (LE) | 12 | 13.6% |
| Mathematics (MA) | 9 | 10.2% |
| Access (AC) | 2 | 2.3% |
| None Identified (NO) | 2 | 2.3% |
| Other | 2 | 2.3% |
| Total | 88 | 100% |

As can be noted from Table 15, the list of identified affordances and limitations, in order from greatest frequency to least frequency, is as follows: Software Features, Motivation, Learning, and Mathematics. The three remaining categories include: Access, None, and Other.

Examples of the affordances and limitations identified by PSTs, not just the types, are given below, according to each of the categories. The bulleted items represent quotations from participants' reflection documents.

*Software features*. These included features such as feedback, ease of use, colors, instructions, and technical features provided by the technology tools. Because 45 of the responses focused on software features, they are not all listed here. Sample participant responses include:

- "It was not a good set up with wires and the projector. The light from the projector was easily intercepted and let parts of the lesson disjointed." (PDS-1)
- "It [Smart Board®] takes a lot of time and thought to create." (PDS-3)
- "Some of the students had a tough time dragging the fractions because they were not familiar with touching the Smart Board®." (PDS-6)
- "It allows the students, if they were to use it on their own, an opportunity to practice with little need of adult help." (PDS-8)
- "Students cannot do it on their own." (PDS-9)
- "The blocks were a little difficult to grab when dragging them on the Smart Board®." (PDS-10)
- "It gives immediate feedback on the wrong answers." (PDS-11)
- "It allowed me to stay focused, manage the time, and can be manipulated to include nearly any kind of graphics and even web links." (PDS-13)

- “Perhaps for some examples that I may come up with on the spot, it may be quicker to draw rather than use the drawing tool that it provides. This however is not a major limitation.” (PDS-14)
- “Easy to see on a projection screen.” (PDS-18)
- “The view can be easily changed by selecting different radio buttons.” (PDS-18)
- “The only limitation that I can address is the issue of handwriting. The handwriting on the Smart Board® is not always clear.” (PDS-20)
- “There was a fear of other internet material popping up during the lesson.” (PS-1)
- “Because the cell phone is small it is not something you can hold up to show to the entire class. It is better used with a small group lesson.” (PS-10)
- “The television makes it possible for the entire class to view a teacher demonstration which is more powerful than just an auditory instruction.” (PS-12)
- “It [bar graph applet] only creates bar graphs.” (PS-14)

Other participant responses echoed the comments shared above.

*Motivation*. Affordances and limitations which focus on motivation included student fun, engagement, and the interactive nature of the technology tools. Participants identified the following affordances and limitations:

- “It can be very interactive and engaging.” (PDS-3)
- “It was slightly more engaging to the students than doing this activity on a regular black/white board would have been.” (PDS-6)

- “Using the overhead all of the time could become boring for the students. It would be more fun for them to play a math game on the Smart Board®.” (PDS-12)
- “It engages the students as they see things move around.” (PDS-14)
- “They really enjoy being able to come up to the board to fill in any information.” (PDS-19)
- “It is easy to create a colorful fun lesson that children are able to interact in.” (PDS-21)
- “Children love using the computer and they love playing games. It was a win-win.” (PS-1)
- “This keeps students interested since they are involved in the lesson.” (PS-4)
- “The tool was very colorful and fun, which motivated the students.” (PS-7)

Note that there were other participants who expressed similar views of the technology tools, so not all of the responses have been included.

*Learning*. Affordances and limitations which focus on learning included general learning issues, not specific to mathematics concepts or ideas. For example, participants identified the following:

- “If not used properly, it can just be a Power Point, telling kids or showing them words about what they are supposed to be learning.” (PDS-3)
- “I think this would be best used for whole class instruction or for pair work. This tool might be a little confusing for students who are unfamiliar with technology so it wouldn’t be good for independent work.” (PDS-4)

- “Concrete examples helped the children to understand abstract concepts.” (PDS-9) [Note the participant did not mention any specific mathematical concepts.]
- “There are some concepts that are difficult to teach on the Smart Board®.” (PDS-21)
- “This does not allow for differentiation for students. It can only be used in whole group activities.” (PS-4)
- “Each student can move at his own pace.” (PS-11)

As noted previously, these affordances and limitations were classified as Learning because the participants did not reference specific mathematical ideas, concepts, or representations.

*Mathematics*. Affordances and limitations which focus on mathematics included a focus on mathematical concepts and representations afforded by the tools. Quotes from participants include:

- “It is a very good hands-on manipulative that can cement abstract mathematical concepts.” (PDS-1)
- “It made the idea of trading before you subtract a little clearer. Students were able to see why we cross out some numbers and add ones to others when using the algorithm.” (PDS-10)
- “The view can be easily changed by selecting different radio buttons to show multiple ways to represent multiplication problems.” (PDS-18) [Note the first part is also an example of Software Features.]

- The tool allows students to visualize 3-D geometric shapes. Also the color changing allows students to count the sides and learn about a specific polyhedron." (PS-8)
- "The only limitation is that all students can do is explore. There are no mathematics problems to solve or deeper knowledge to gain." (PS-8)
- "You can create very large numbers on the cell phone, which can lead to a discussion about place value." (PS-10)
- "It is a wonderful applet for introducing, using, and creating bar graphs." (PS-14)

Note these affordances and limitations were tool-specific, in that they focused on specific features of the tools used by the participants, rather than comments about technology tools in general.

*Access*. Affordances and limitations which focus on access included pre-service teachers concerns with students being able to access a particular technology tool. One participant (PS-12) identified physical access to technology as a limitation. For example, this participant stated:

- "The laptops are limited in that there are only 22 available on the traveling carts and two stay in the classroom. If you have more than 24 students, then you must have students share or you must try to borrow laptops from other $4^{th}$ or $5^{th}$ grade classrooms."

Note that this participant did also identify other affordances and limitations, which would fall under the other categories.

*None identified*. Two participants specifically stated they did not recognize any limitations or constraints in the technology tool. One participant simply replied by saying "none" (PDS-11) and the other stated, "From my experience, I did not find any limitations." (PDS-15).

*Other*. One participant (PS-5) identified two affordances/limitations which could not be classified in any of the other established categories. This participant identified the following affordance: "The benefits will be that students will need to know how to use calculators for the rest of their lives." This participant also identified human error as a limitation.

How, then, did the PSTs design their lessons using technology? Research Question 3 asked: How do these roles influence the ways in which pre-service elementary teachers plan for mathematics instruction? The lesson plans and reflection documents were analyzed and classified according to the way technology was integrated into the lesson plan. The four lesson plan designs which emerged from the data are: display, productivity, review & practice, and student exploration.

A lesson plan design which was coded as display included a display or demonstration at the front of the room (typically on the Smart Board®), with the teacher maintaining control. If students were allowed to come up to the Smart Board®, they did so to demonstrate something to their classmates. The lesson plan design which was coded as productivity included the use of an applet to create bar graphs. A lesson plan design which was coded as review & practice focused on students using a technology tool to review and practice a skill, such as multiplication. Finally, a lesson plan design which was coded as student exploration included technology tools where students worked, individually or in groups, to explore a specific mathematical concept. Note the locus of control gradually shifts from teacher (display) to student (student exploration.)

Table 16 notes the number of PDS and PS teachers (as a combined group) who designed a lesson plan using technology in each of these four ways. The horizontal axis notes these four lesson designs: display, productivity, review & practice, and student exploration. The vertical axis identifies the PSTs' roles to technology: Master, Master-Servant, Servant, and Servant-Partner. Of the 35 participants, 28 actually used technology, so only those 28 participants are recorded in the table. Each of the cells indicates the number of teachers of a particular role who used technology in one of the four previously-mentioned ways.

Table 16.

*Relationship of Teacher to Technology and Type of Lesson Design Employed*

| Role | Display | Productivity | Review & Practice | Student Exploration |
|---|---|---|---|---|
| Master | 8 | 1 | 3 | 0 |
| Master-Servant | 3 | 0 | 0 | 2 |
| Servant | 6 | 0 | 1 | 1 |
| Servant-Partner | 1 | 0 | 0 | 2 |

Among the participants, the percentage of each of the following lesson designs was observed:

- Display: 64.3%
- Productivity: 3.6%
- Review & Practice: 14.3%
- Student Exploration: 17.9%

Display was the lesson design practice most commonly found among participants. More of the display lessons were found at the Master and Master-Servant roles (n=11) than at the Servant and Servant-Partner roles (n=7). Student exploration was not a lesson design among the Master role, but it was among the Master-Servant, Servant, and Servant-Partner roles.

Not surprisingly, the locus of control was the teacher for the majority of the teachers. However, the higher the level in the hierarchy (beginning with Master-Servant), the more control tended to be shared among the students. This is in line with previous research which has shown that teachers at the Partner role tend to relinquish control of the technology and encourage students to be responsible for their own learning.

The following sections provide examples of each of the four types of lesson design, with excerpts from the participants' lesson plans and/or reflection documents. For each lesson design, the following information is included: the lesson objective, the type of technology tool used, additional information about the lesson itself, the role between the teacher and the technology tool.

*Display*. PDS-20, who was assigned to fifth grade, designed a lesson which used technology for display or demonstration purposes. The lesson objective was as follows: "Students will be able to identify the missing number in two equivalent fractions by multiplying by 1 (written as a fraction)." The technology tool used by this PST was the Smart Board®, upon which she displayed various slides she had created. In her lesson plan, this PST stated the following role of technology in the lesson:

> Slides 3, 4, 5, and 6 on the Smart Board® lesson introduce this concept [identifying the missing number in two equivalent fractions by multiplying by 1] using Magic Mr. 1. Each slide is broken up into different sections. Slide three introduces the concept, discussing the algebraic concept of "n". Slide four shows how Magic Mr. 1 works, slide five shows the math behind the magic, and slide six shows how does Magic Mr. 1 help me. These four introductory slides will be used to teach this math concept.

Figure 9 is a screenshot of slides 3, 4, 5, and 6.

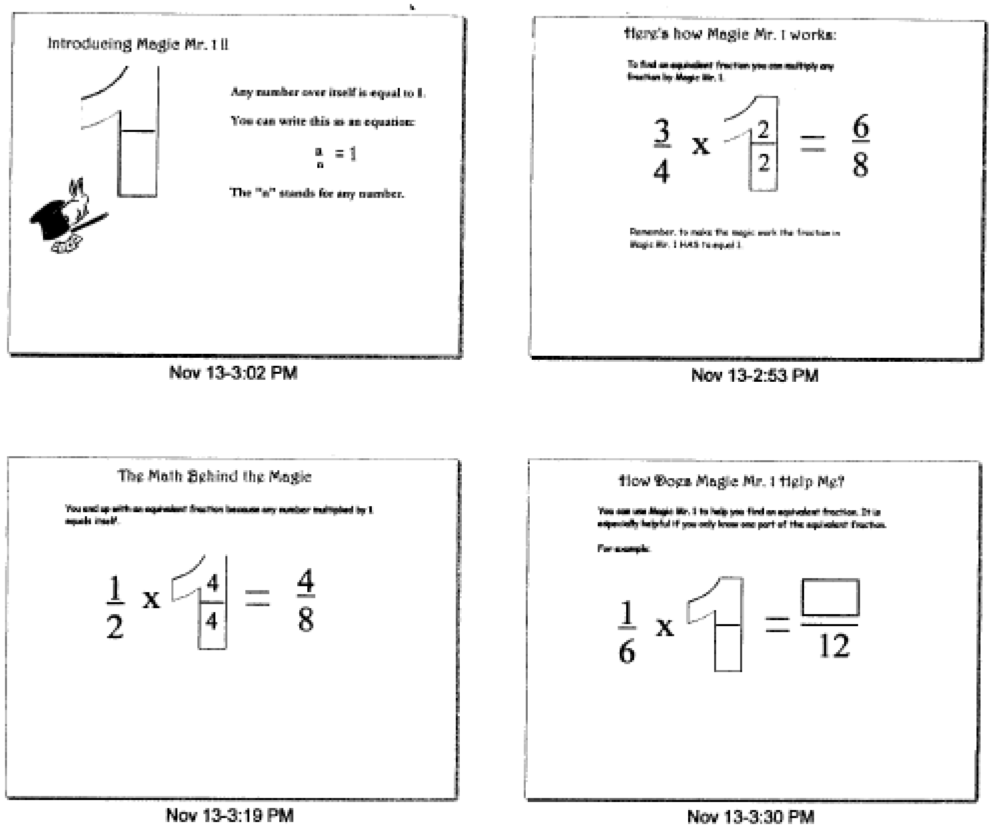



*Figure 9.* Screenshot of PS-20's Smart Board® slides.

As the slides progressed past slide 6, the teacher modeled the steps in each slide. Finally, students were given a worksheet in which they matched equivalent fractions with the "Magic Mr. 1." Students worked independently to complete the problems on the worksheet, as the PST walked around the room to check on the students' progress.

At no point during the lesson did students have the opportunity to come up to the Smart Board® or otherwise engage with the technology. Throughout the lesson, the PST remained in control of the technology. Other features of the lesson plan and reflection document also supported this PST's classification as the Master role. For example, when asked about her ideal lesson, this PST replied: "I would have used the same technology. The students really respond well to having the norm of the Smart Board® lesson. The students are engaged and eager to answer questions and participate in the lesson. I would have kept everything the same, especially in the technology portion." The fact that she would not have made any changes is consistent with the Master role.

Further, when asked what benefits or features she recognized in this technology tool, PST-20 responded by saying, "There are many benefits to the Smart Board®. The students are able to interact with the Smart Board® and have a clear visual which I can control. I can add text, numbers, pictures, etc." Notice, however, that this PST did not allow students to interact with the technology tool, and she discussed on what SHE could do with her knowledge of the technology. These comments, as well as her use of the technology, are consistent with the Master role.

*Productivity.* PS-14, who was assigned to second grade, designed a lesson which used technology for productivity. The lesson objective was as follows: "Given a demonstration and mini lesson on bar graphs, students will help construct bar graphs with data provided by the students, and use subtraction to process data from a bar graph." The technology tool used by this PST was the Bar Grapher Tool, as found on the Illuminations website (http://illuminations.nctm.org/ActivityDetail.aspx?ID=63). Figure 10 is a screenshot of this technology tool.

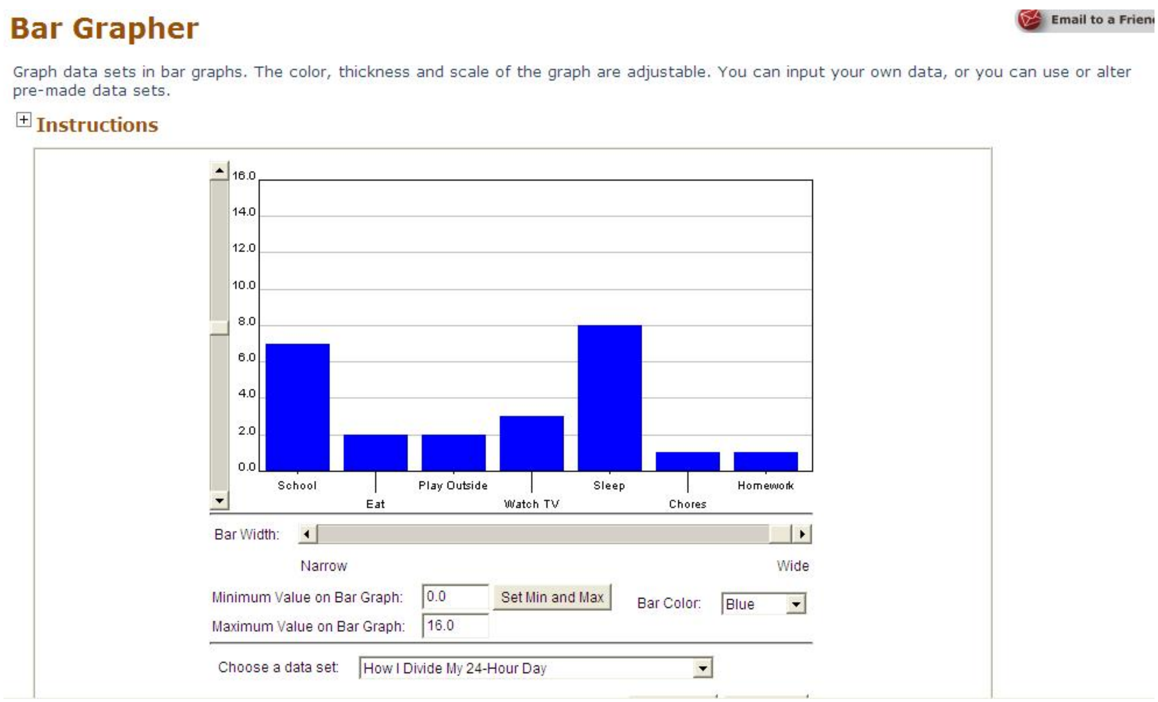



*Figure 10.* Illuminations Bar Grapher Tool.

The lesson plan was divided into four major sections: link (5 minutes of whole class instruction); engage and educate (15 minutes of class discussion); active learning (20 minutes of whole class and partner learning); and reflect (5-10 minutes of group discussion.) It was during the active learning section of the lesson plan in which students were engaged in using the technology tool. In her lesson plan, this PST included the following directions:

> Next, open the Bar Grapher Tool and project for students to see. This tool allows you to enter your own data and graph it. Create a bar graph for students to view. Once you have created the bar graph, pose questions

which require students to use subtraction to compare. (Note: It would be best if you enter your own data for this class example, so the numbers are whole numbers and are relevant to the students' lives.) Discuss the answers students recorded in their math journals. Teachers should discuss the bar graph further posing questions like [and then the PST included some possible questions to pose to the students.]

Note that these instructions in the PST's lesson plan were almost verbatim of the Illuminations lesson plan which accompanied this technology tool. The students then went on to use the bar graph tool to create their own bar graphs in pairs.

PS-14 was classified as the Master role for several reasons. Essentially she copied and pasted an existing lesson plan and used the technology as prescribed by the lesson plan. Technology was used in the manner prescribed by someone else, revealing her own limited knowledge of the technology. In addition, when asked if she would change her lesson in any way, this PST replied, "I would not have changed the technology I chose. I believe it effectively demonstrated a bar graph." These comments, as well as others in her reflection document, are consistent with the Master role.

*Review & Practice.* PS-12, who was assigned to a fifth grade class, designed a lesson in which technology was used by students to review and practice divisibility and division problems. The lesson objective was as follows: "Given the Harcourt website, students will review divisibility, create division problems with remainders, experience division with one-digit divisors, and practice division with two-digit divisors." The technology tool used by this PST was one provided by a textbook publisher, http://www.harcourtschool.com/activity/elab2004/gr5/. Figure 11 is a screenshot of one of the applications of this technology tool.

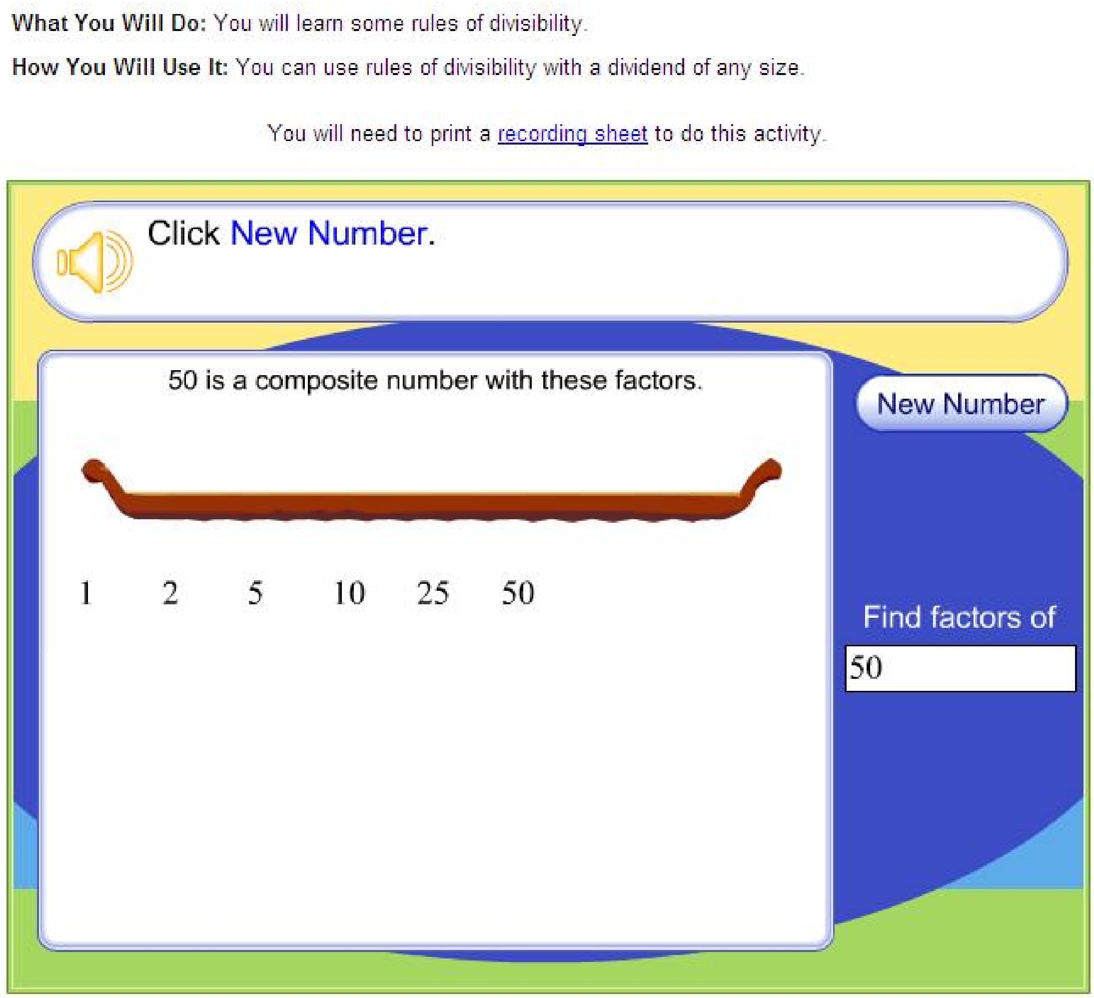



*Figure 11*. Divisibility Tool.

The PST began the lesson by asking students “Who would like to learn math by playing computer games today? Who would like to have the computer give you the answers to your division problems?” She then briefly discussed the previous week’s division lesson, distributed a worksheet, and modeled the divisibility activity on the projection screen. Then, students were given laptops to complete the various types of problems on the worksheet (as noted in the lesson objective.) She concluded the lesson by asking students if the website “helped them to learn any helpful math division tips that would help other students.”

PS-12 was classified as the Servant role primarily for the way in which students used the technology tool. Technology was used as a substitute for paper-and-pencil work, which is a characteristic of the Servant role. Further, concept exploration was not the focus of this lesson. When asked to identify the affordances of this technology tool, this PST replied: “The Harcourt website not only had great division activities, it had great worksheets for the students to complete as they navigated the website.”

*Student Exploration.* PS-8, who was assigned to a third grade class, designed a lesson in which technology was used by students to explore geometry and spatial concepts. The lesson objective was as follows: “Students will be able to analyze characteristics and properties of three dimensional geometric shapes and name each of the faces of common geometric solids.” The technology tool used by this PST was the Geometric SolidsTool, as found on the Illuminations website (http://illuminations.nctm.org/ActivityDetail.aspx?ID=70). Figure 12 is a screenshot of this technology tool.

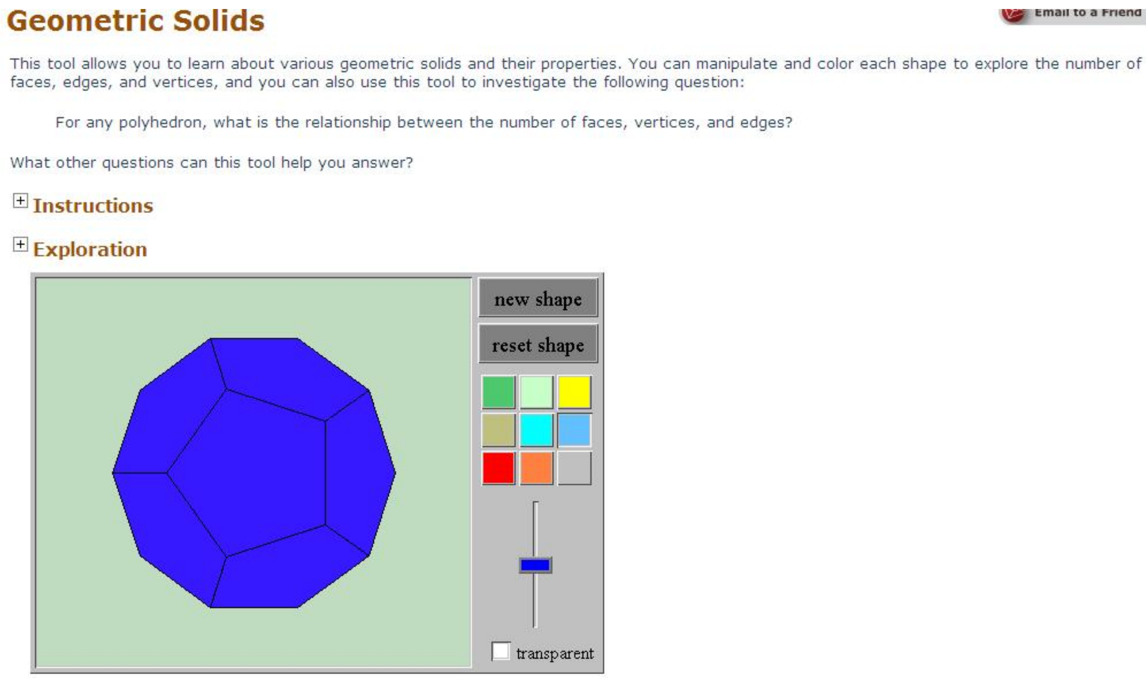



*Figure 12.* Geometric Solids Tool.

The bulk of the lesson was devoted to student exploration with the technology tool. To begin, students first were allowed time to explore the technology tool, and they were given simple instructions as to how to use it. Then, students were directed to spin the geometric shapes on the tool and explore those different shapes. In their math journals, students were asked to record what they discovered about the shapes and to sketch the sides of a couple of the figures.

After students had ample time to explore the geometric solids, and record their observations, they were asked a question: “What is one thing all the shapes have in common?" A class discussion then followed, and students were guided to important conclusions about the names and faces of the geometric solids.

Notice that for the bulk of the lesson, students were in control, not only of the technology, but also of their own learning. When asked why she selected this technology tool, the PST responded, "I thought that this tool made it easier for students to visualize polyhedra and rotate the. Also, the color tool made it easy to count the number of sides of the polyhedra." When asked if she would have made any changes, this PST stated that she "would keep the same technology tool because the students enjoyed it and it helped the students gain a better understanding of geometric shapes." She also noted that she would have "demonstrated how to use the tool on the computer instead of giving them instructions" had a projector and screen been available. These comments, along with others on the reflection document, are consistent with the Servant-Partner role.

# 5. CASE STUDY

A separate chapter was designated for a case study of a pre-service teacher selected from the group of participants. This chapter is divided into three major sections. The first section gives background information about the pre-service elementary teacher, her fieldwork placement, and the lesson taught using technology. The second section addresses the research questions previously identified in this study in light of this pre-service elementary teacher's uses of technology. The third section includes a summary and discussion about the results for this pre-service elementary teacher in light of the study. Throughout this chapter, a pseudonym is used, and this pre-service elementary teacher is referred to as Doreen. It is important to note that the comments and descriptions in this chapter are based on Doreen's lesson plan, reflection document, and responses to interview questions. The researcher did not actually observe the lesson taught by Doreen.

## Background Information

### *Information about Doreen*

Doreen is a resident of Northern Virginia in her early 50s. Her ethnicity is Caucasian. Doreen recently joined the elementary education program for second career teachers. Throughout her life, Doreen has seen computer technology advance from punch cards to the current advanced technologies. This program is her first experience in teaching elementary aged children.

*Information about Doreen's Fieldwork Placement*

Doreen was placed in a Partner School (PS), where she was expected to complete 15 hours of fieldwork during the semester. At the same time she was completing her fieldwork requirements, she was enrolled in the Elementary Math Methods course. Doreen was assigned to a fifth grade classroom at a local public elementary school. The class to which she was assigned included 22 students. None of these students were identified with learning disabilities or special needs, and they all spoke English as their first language. Doreen noted that these particular students were grouped as the middle range of ability for fifth grade math.

The school itself does not have Smart Boards® in the classrooms. There is only one Smart Board®, and that is located in the computer lab. There were functional issues with the Smart Board®, namely the pen did not work. The computer lab has to be reserved, usually in 30-minute blocks. The students in Doreen's class had used the computer lab previously, so they were familiar with using technology.

*Information about Doreen's Lesson Plan Using Technology*

Doreen was assigned this particular lesson by her cooperating teacher. The objectives of the lesson, as identified by Doreen, were as follows:

- The students, given a dividend expressed as a decimal through thousandths and a single-digit divisor, will be able to find the quotient, by completing practice problems with 80% accuracy.

This lesson objective corresponds directly to Virginia Standard of Learning 5.6: The student, given a dividend expressed as a decimal through thousandths and a single-digit divisor, will find the quotient. The other lesson objective was:

- The students will be able to demonstrate correct ordering of decimal numbers by choosing a number that falls between two decimal numbers.

The time allotted for each of these lesson objectives was about equal (35 minutes per each objective.)

Doreen incorporated two websites on the Smart Board® and allowed students time at individual computers to use one of the websites. Her reason for doing so was the limited amount of time available in the computer lab and the partially-working Smart Board®. Both websites were projected onto the Smart Board® for the entire class. Of the portion of the lesson conducted in the computer lab, about half of the time was spent on whole-class instruction, and the other half was spent on individual work in front of the computers.

Doreen introduced the lesson by projecting a Brainpop video about decimals as a review on the Smart Board®. As a class, the students completed the interactive quiz following the 5-minute video. Next, Doreen projected a website on the Smart Board®. The website, www.aaamath.com/B/dec56ax2.htm#section2/ shows students the traditional division algorithm and gives them practice problems. Doreen used the website to teach students the steps for dividing decimals using a 1-digit divisor. They were then given 10 minutes at individual computers to practice division problems independently. Doreen allowed students to use paper and pencil to compute the answers (if they could not do so mentally) and then record the answers in the correct location on the website. The website gave students immediate feedback. Figure 13 shows the portion of the lesson plan in which Doreen used technology. Figure 14 shows a screenshot of the website used by students.

Instructional Strategy:

Session 1 in Computer Lab (30 minutes)

- Put http://www.aaamath.com/B/dec56ax2.htm#section2 Math website on whiteboard
- Teach steps to standard algorithm for dividing decimals using 1 digit divisor:
    - Procedure is same as division of whole numbers except remember to place decimal in quotient exactly above where it is in the dividend.
- Have students calculate practice problems on website for about 10 minutes. If it is too difficult for them to compute mentally, use paper and pencil, and insert answers into program, checking for accuracy. Print score sheet and hand in at end of class for assessment.
- Pull up flipchart and show story problems using decimal division on whiteboard.
- Have students volunteer to come up to board, write equation, and check answer.

*Figure 13.* Doreen’s lesson plan.

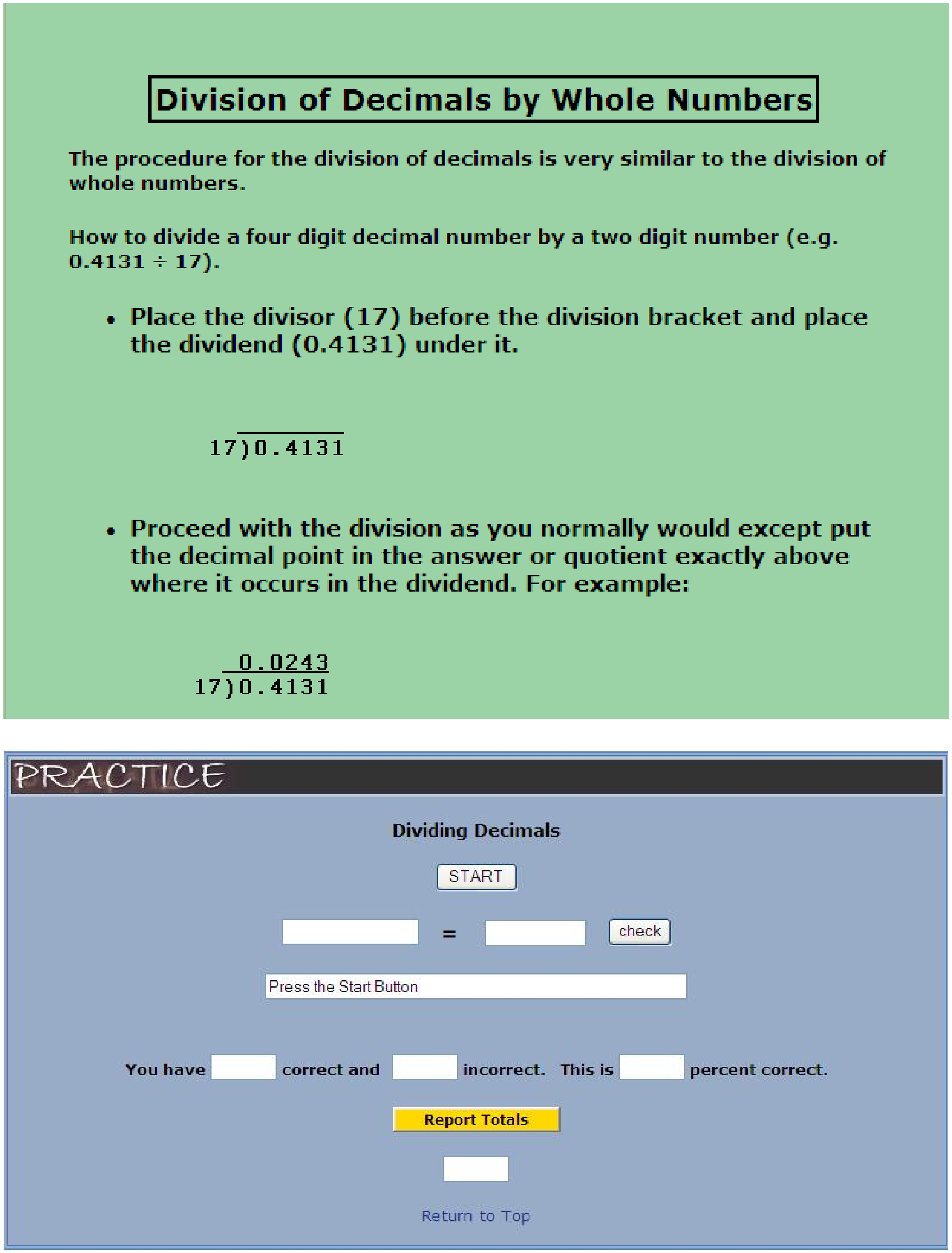



*Figure 14*. Screenshot of Doreen’s technology tool.

After the 30 minutes of instruction via technology, the students then returned to the classroom for the other half of the lesson. In their classroom, students used base-10 grids to compare decimals. Students shaded base-10 grids and were asked questions about decimals. No technology was used for this portion of the lesson. Only paper and pencil were used. Doreen stated that, for the entire lesson, she felt comfortable with the math content of the lesson.

In her lesson plan, Doreen noted that her assessment would be a worksheet of division problems completed by the students, without the use of technology. In addition, in the section of the lesson plan entitled *Differentiation,* Doreen noted that "no adaptations were made for individual learners."

## Research Questions: Results for Doreen

### *Research Question One*

Research question 1 was: What roles exist between pre-service elementary teachers and the technology tools they choose to integrate in their mathematics lesson plans? Doreen was classified as the Master role based upon her use of technology (as noted in the lesson plan), her comments on her reflection upon the lesson, and her responses to questions in the interview. Quotations and examples from each of these data sources are included to provide support for the classification of Master.

During the interview, Doreen made comments about her use of technology and reasons for doing so. When asked about the lesson plan, its main thrust, and the ultimate goal, Doreen responded:

> My teacher asked me to teach the students how to divide decimals using long division standard algorithm. Since this is a procedure, it was difficult to use technology in a “creative” way or to allow the students to “construct their own meaning”. My ultimate goal was for the students to learn the steps of the algorithm, and to be able to carry them out accurately. I used the Smart Board® to demonstrate the steps and then the “AAA Math” website for the students to practice doing problems, entering answers, and then getting immediate feedback from program if answer was correct or not.

Doreen’s responses are consistent with the Master role. Doreen did not view technology as something which could easily allow students to construct their own meaning in the context of division of decimals. Notice Doreen was concerned with demonstrating “steps” and students learning an algorithm. She focused on the limitations of the technology, and she did not seek out other alternatives which might promote conceptual development. Her knowledge of alternative technology tools was quite limited, and when asked how she went about selecting the technology tool, she simply responded, “I selected the Smart Board® and website to use because it fit the assignment I was given to teach the best.” When asked if she would have done anything different in her lesson, Doreen responded by saying, “I most likely would not have used technology to teach this particular concept because I don’t think teaching steps to an algorithm is particularly well-suited for using technology.”

Throughout the lesson plan, the reflection, and the interview, it was clear that Doreen maintained control of the technology before allowing students to practice on their own. When students did use the technology, they did not interact with each other. Doreen was asked about the role of communication in this lesson. She replied, “The role of communication in this lesson was to directly instruct the students in the steps of the division algorithm.” When asked about the role of technology in communication, Doreen focused on the interaction of the student with the technology. Thus, communication at this point was limited to student and computer, rather than student to student, student to teacher, and so on.

In this lesson, students used technology to practice division problems. In the literature, using technology as a substitute for tasks which can be performed by paper and pencil, for example, is often an indication of the Servant level. However, Doreen made the following remark about students using paper and pencil: “The problems were hard to do mentally, so I allowed the students to use scratch paper to divide and then enter their answers to check.” This response is almost the reverse of what the literature says about using technology as a substitute for paper and pencil. Doreen used paper-and-pencil almost as a supplement to technology. Or, another way of putting it, Doreen allowed an alternative to technology. Yes, the students were expected to answer questions mentally, but Doreen chose a site which required mental computation, and then gave students an “out.” This is not to say she should not have allowed paper-and-pencil, but Doreen’s choice of technology further supports her classification as Master.

Unlike the second half of the lesson (in which students were involved in an exploration of a concept), Doreen did not use the opportunity to engage students in a discussion about how they arrived at their answers. Doreen could have posed questions to her students to challenge them to think about how they went wrong with their work. She could have engaged students in partner conversations in which they assisted each other or posed questions or problems to each other. Doreen could have identified other technology tools, such as those found on the National Library of Virtual Manipulatives or Illuminations, or she could have asked her cooperating teacher or methods instructor for further guidance. Instead, Doreen selected one website to use with her students, despite its many limitations. Thus, the classification of Master is maintained.

Another point needs to be made here. The role of technology identified for Doreen could also be a function of her philosophy of teaching. During the second half of the lesson, Doreen engaged her students in concept exploration of decimal numbers. She asked students to use decimal grids to promote their number sense and conceptual understanding of decimal numbers. However, she did not use technology for this portion of the lesson. During the first half of the lesson, in contrast, Doreen maintained her view of division with decimals as a procedural experience. Doreen did not see the necessity for developing conceptual understanding of decimal division. Thus, Doreen's pedagogical knowledge influenced her lesson design and use of technology.

Zbiek, Heid, Blume, and Dick (2007) note that "a teacher's readiness to use a particular form of technology and the nature of how a teacher's use of the technology unfolds center around how the teacher's practice and the nature of that technology align"

(p. 1187). Doreen's use of technology can be positioned within the concept of pedagogical fidelity, which is the extent to which a teacher believes that "a tool allows students to act mathematically in ways that correspond to the nature of mathematical learning that underlies a teacher's practice" (p. 1187). In other words, because Doreen views the learning of decimal division as an algorithmic (rather than conceptual) mathematical topic, her use of technology is influenced by her views of how the learning should be achieved by the students.

*Research Question Two*

Research question 2 was: How do various internal factors (which include personal beliefs, as well as prior experiences with technology) and external factors (which include curriculum goals, cooperating teachers, and availability of technology) influence these roles (which may include master, servant, or partner, as well as others) observed between the pre-service elementary teachers and the technology tools?

*Personal beliefs and prior experiences with technology*. During the interview, Doreen was asked how her personal experiences with technology have influenced her views of technology. Doreen responded:

> I was introduced to technology and computers via punch cards and witnessed every adaptation/innovation/advancement in technology since the beginning-not all of which was successful and most certainly, always a large expense. But it has progressed beyond a "novelty" or "extravagance" and now become more affordable and available for most people and integrated in our daily lives. I believe it is a tool like any other tool and I

> agree with Bill Gates when he said “we do not have a pencil lab in the school so why do we have a computer lab?” I think computers are cheap enough now to have a laptop for every child in every classroom in order to truly integrate technology in our lessons. In this way, it would be another tool available to the teachers and students for immediate access as needed throughout the day not something that needs to be “reserved” and “scheduled” in advance. If it is not convenient and accessible, it will not be used.

It is obvious that Doreen believes in the use of technology, and she has witnessed many changes in the technology available to students. The electronic survey tool used in this study did not capture respondents’ identities, so her comments on the survey could not be included here.

*Curriculum goals and cooperating teacher*. Doreen noted that she selected her technology after being assigned the particular lesson objective. As noted in Chapter 4, the identification of the technology to support the objective was typically found at the higher end of the hierarchy, but this was not a direct correlation. Thus, this statement by Doreen does not violate the previous results with regard to curriculum goals.

Doreen noted that the lesson objective was assigned to her by the classroom teacher. This comment is not indicative of any particular role. However, when asked how the cooperating teacher influenced the technology tool she selected, Doreen responded: “She did not directly discuss the lesson with me, but by assigning an algorithm to me to teach, I think she did influence the technology tool I selected indirectly by limiting my choices of tools." This statement supports earlier discussion about Doreen's limited knowledge of technology tools and their potential to support conceptual development. Thus, it was not the cooperating teacher who directly influenced the role in which Doreen found herself; rather, Doreen identified her cooperating teacher as a reason for selecting the technology tool she used.

*Availability of technology.* Doreen was asked how her fieldwork placement and experiences had influenced her views of technology. Doreen responded, "The school I was placed in did not use technology at all in math and had limited availability of computers which negatively influenced my views on using technology in the classroom to teach Math on a regular basis." Unlike the results discussed in Chapter 4, here it is clear that the availability of technology did, in fact, influence the role in which Doreen was classified.

### *Research Question Three*

Research question 3 was: How do these roles influence the ways in which pre-service elementary teachers plan for mathematics instruction? It included the following sub-questions:

a) When planning for instruction, what criteria do pre-service elementary teachers use to evaluate technology tools for mathematical learning?

b) When planning for instruction, what perceived affordances and limitations do pre-service elementary teachers identify with respect to technology tools for mathematical learning?

Doreen identified four criteria for evaluating her technology tools. The first criterion, accessibility of Smart Board®, focused on when the Smart Board® would be available to her. The researcher classified this as a Software Feature because of further comments made by Doreen about the features of the Smart Board® which did and did not work. The second criterion, ease of use for students, was classified as a Software Feature. This is in line with the coding schema identified in Table 9. The third criterion, online applet to practice algorithm, was classified as Mathematics, because Doreen stated that it helped students learn and practice an important mathematical skill. Finally, the fourth criterion, informative and entertaining Brainpop video, was classified as Motivation, which is in line with the coding schema identified in Table 9.

Thus, Doreen identified two criteria which were classified as Software Features, one criterion which was classified as Mathematics, and one criterion which was classified as Motivation. Three of these four criteria are part of the organizational category Surface Features. Other comments made by Doreen, in the lesson plan, in her reflection, and in her interview, support these findings about the criteria she used to evaluate her technology tools. During the interview, Doreen was asked if she would change any of these criteria now that the lesson had been taught and she had time to reflect upon the lesson. Doreen replied that she would not change any of her criteria.

When asked about the benefits or features in this technology tool, Doreen responded, "The benefits of the practice on the website is that each student can move at his own pace and it provides immediate feedback to the student if he is right or wrong." The researcher classified this affordance as both Learning and Software Features, because

Doreen focused on the pace of the student (Learning) and the feedback given by the website (Software Feature). When asked about the limitations or constraints of this technology tool, Doreen responded, “The problems were hard to do mentally so I allowed the students to use scratch paper to divide and then enter their answers to check.” The researcher classified this limitation as both Learning and Mathematics, because Doreen was focused on the problems themselves, not the actual technology tool, and was taking into account students’ abilities and the types of mathematical problems presented by the website.

Doreen was asked what representations the technology tool included. Doren responded, “This tool uses symbolic form of representation by using numeral for division of decimals algorithm.” When asked how she used the technology tool, Doreen selected the following two uses (from a given list):

- Teacher tool to demonstrate a skill or procedure
- Student practicing a skill or topic

Doreen noted that she used the technology in this manner because that was the objective of the lesson.

## Summary and Discussion

This chapter has presented an in-depth analysis of one PS pre-service elementary teacher who participated in the present study. Doreen, who was assigned to a fifth-grade classroom, wrote and taught a lesson plan which focused on division of decimal numbers by one-digit divisors. Doreen integrated technology in three ways:

1) A brief video, projected onto a Smart Board®, which served as a review and an introduction to the lesson;

2) A review and practice tool (website) projected onto a Smart Board®, which was used as a method of teaching the traditional division algorithm;

3) The same website for use by individual students to learn and practice the algorithm at computers.

As noted in Chapter 2, Garofalo, Drier, Harper, Timmerman, and Shockey (2000) identified five guidelines for appropriate uses of technology in mathematics education. Of these five goals, only one was met by Doreen's lesson: Address worthwhile mathematics with appropriate pedagogy. The other four were not addressed, neither in the lesson plan, nor in the reflection which followed.

In addition, the researcher compared the lesson plan and reflection to the five NCTM Process Standards (2000) to identify which ones were promoted in this particular lesson. Of the five Process Standards, Problem Solving, Reasoning & Proof, Communication, Connections, and Representation, none of these was promoted in the lesson. In particular, the researcher did ask Doreen about the role of technology in promoting communication, and Doreen noted that she used her communication to directly instruct students.

After careful analysis, Doreen was classified as the Master role. There were numerous elements of her lesson plan, as well as in her reflection and interview, which support this classification. The researcher compared Doreen's lesson plan, reflection, and interview responses to the rubric in Figure 4, and noted the following characteristics consistent with the role of Master. Doreen had limited knowledge of technology tools and expressed a belief that there were no tools which could support conceptual learning of the topic. She focused on several of the problems with the technology. She would not make any changes to her lesson plan, other than perhaps removing the technology altogether. None of the comments made by Doreen, nor any of the features of the lesson plan justified a classification of Doreen at a higher level of the hierarchy.

Due to the limited response to the researcher’s request for interviews, only a Master role could be highlighted as a case study in the present research project. The researcher had hoped to highlight other roles to add to the body of literature. However, this case study has provided a rich example of a pre-service teacher who found herself situated within the Master role of teacher and technology. The following chapter considers the participants as a group, but at the same time, it poses questions for future research in light of Doreen and the other pre-service teachers who participated.

# 6. DISCUSSION

This study explored the roles which exist between pre-service elementary teachers and the technology tools they integrate in their mathematics lesson plans. In addition, this project explored how pre-service elementary teachers' conceptions of technology influence the ways in which they evaluate technology tools for mathematical learning. The purpose of this chapter is to discuss the results of this study, which were guided by the following questions:

1) What roles exist between pre-service elementary teachers and the technology tools they choose to integrate in their mathematics lesson plans?
2) How do various internal factors (which include personal beliefs, as well as prior experiences with technology) and external factors (which include curriculum goals, cooperating teachers, and availability of technology) influence these roles (which may include master, servant, or partner, as well as others) observed between the pre-service elementary teachers and the technology tools?
3) How do these roles influence the ways in which pre-service elementary teachers plan for mathematics instruction?
    a) When planning for instruction, what criteria do pre-service

elementary teachers use to evaluate technology tools for mathematical learning?

b) When planning for instruction, what perceived affordances and limitations do pre-service elementary teachers identify with respect to technology tools for mathematical learning?

In light of these research questions, and after a thorough analysis of the qualitative data collected in this study, eight major conclusions were drawn. These conclusions are presented here and discussed in detail in the sections which follow.

The following sections present further discussion about these major conclusions. The first section addresses the roles between pre-service teachers and technology tools (Conclusions 1a and 1b). The second section addresses the various internal and external factors which influenced these roles (Conclusions 2a and 2b). The third section addresses the criteria for evaluating technology tools (Conclusion 3a), perceived affordances and limitations of those technology tools (Conclusion 3b), and lesson design issues (Conclusions 3c and 3d). The remaining portion of this chapter discusses the limitations of the study, the implications of this study to mathematics teacher educators, and implications for future research.

Conclusion 1a: Seven roles between pre-service teachers and technology were identified among the participants in this study. They are: Technology Not Used (TNU), TNU – Willing, TNU – Master, Master, Master – Servant, Servant, and Servant – Partner. Of these seven roles, only two have been previously identified by the literature: Master, and Servant. (Partner and Extension of Self also exist in the literature, but they were not found in the present study.)

Conclusion 1b: Sixty percent of the participants were classified as Master (37%) or Servant (23%), which are roles already established in the literature. Forty percent of the participants were classified as having roles identified by this present study.

Conclusion 2a: Pre-service teachers tended to choose the objective first and used technology to support the lesson objectives were found at the higher end of the hierarchy (Master-Servant, Servant, and Servant-Partner). Pre-service teachers who tended to give no explicit statement regarding the role of the objective to the lesson plan were found at the lower end of the hierarchy (in particular, Master)

Conclusion 2b: Prior experiences with technology, access to technology, and cooperating teachers had no apparent influence on the roles between the pre-service teachers and technology. However, since Smart Boards® were readily available in most classrooms and/or schools, they were used the most often by the pre-service teachers.

Conclusion 3a: Pre-service teachers overwhelmingly (79%) identified Surface Features (Software Features and Motivation) as the criteria they used to evaluate their technology tools. Content and Instruction were the criteria identified only 21% of the time.

Conclusion 3b: Pre-service teachers primarily identified Software Features (51%) and Motivation (18%) as the perceived types of affordances and limitations of the technology tools. In contrast, Learning and Mathematics were identified as affordances and limitations 14% and 10% of the time, respectively.

Conclusion 3c: The majority of pre-service teachers (64%) designed lessons in which technology tools were used for display or demonstration purposes, whereas only 18% of the pre-service teachers designed lessons which focused on student explorations of concepts.

Conclusion 3d: The curriculum goals, technology tools, and the lesson design are all characteristics of the roles. Taken together, they help demonstrate pre-service teachers' levels of TPCK (technological pedagogical content knowledge).

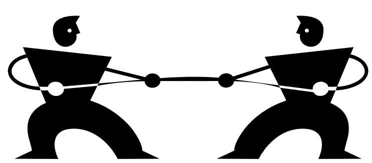
## Roles Between Pre-Service Teachers and Technology Tools

Seven roles between pre-service teachers and technology were identified among the participants in this study. They are: Technology Not Used (TNU), TNU – Willing, TNU – Master, Master, Master – Servant, Servant, and Servant – Partner. Of these seven roles, five were unique to this study and not previously identified in the literature. The other two roles, Master, and Servant, have been identified previously by Goos et al. (2000; 2003). (Partner and Extension of Self also exist in the literature, but they were not found in the present study.)

The fact that TNU, TNU – Willing, and TNU – Master emerged from this study indicates that there are technology-use constructs that may be unique to pre-service teachers, particularly in this group of participants. In the present study, the reasons for this included curriculum constraints (TNU or TNU – Willing) or beliefs about the role of technology in mathematics education (TNU – Master). It is important to note that several participants did not identify their reason for not integrating technology.

The Master – Servant role was identified among participants who were not firmly located in either the Master role or the Servant role. These participants demonstrated characteristics of both roles. Similarly, the Servant – Partner role was identified among participants who were not firmly located in either the Servant role or the Partner role. Figures 9 and 10 highlight the tension between consecutive roles. As demonstrated in Figure 15, a pre-service teacher can feel limited by or constrained by the technical features of the technology tools or could focus solely on the problems with the technology. At the same time, the pre-service teacher may note that other possible uses of technology exist, even if he/she did not explore other uses in their lesson plans. Similarly, as demonstrated in Figure 16, a pre-service teacher may feel the need to maintain control of how students use the technology. Yet, at the same time, these teachers may feel the need for students to explore concepts using technology.

Focused on the
limitations of the
technology used

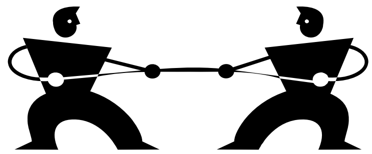


Recognizes other
possible uses of
technology

Master~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~Servant

*Figure 15*. Tension which exists between the Master and Servant roles.

Teacher controls
the use of
technology by
the students



Recognizes the
need for students
to explore
concepts via
technology

Servant~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~Partner

*Figure 16*. Tension which exists between the Servant and Partner roles.

Are the roles between pre-service elementary teachers and technology, in fact, static? Can these roles change over time, particularly as pre-service teachers complete their coursework and fieldwork experiences? The findings indicate that the curriculum goals influence the role between the pre-service teacher and the technology they use. Thus, as the lesson changes, the role could potentially change. Therefore, further research is necessary to determine whether or not these roles are static. The seven roles identified in this study are displayed in Figure 5, in which a staircase is used. The researcher views these seven roles as a hierarchy. Yet, even though the roles form a hierarchy, a pre-service teacher may change his or her position on the staircase.

## Internal and External Factors Which Influence the Roles Between Teachers and the Technology Tools

### *Personal Beliefs*

PST personal beliefs about technology were not readily apparent in the data collected. Actual statements of personal belief were not always noted in the reflection documents. Thus, the researcher was not able to address the potential influence of personal beliefs on the role between the pre-service teachers and the technology. (See Implications for Future Research, below, for further discussion.)

*Prior Experiences with Technology*

Prior experiences with technology had no apparent influence on the roles between the pre-service teachers and technology. Most of the participants indicated a regular use of technology in their daily lives. In particular, participants often indicated that they used email, word processing, and text messaging multiple times each day. This would suggest a group of pre-service teachers who are comfortable using technology in their everyday lives, and thus they did not feel hindered by a lack of prior experiences with technology.

*Cooperating Teachers*

Cooperating teachers did not appear to influence the roles between the pre-service teachers and technology. When asked about the impact their cooperating teachers had on their use of technology in their lesson plans, the participants responded in one of five ways: no influence, cooperating teacher doesn’t use technology (or is limited in his/her technology use), cooperating teacher identified technology and/or taught the PST how to use it, cooperating teacher is supportive of technology use, and strong influence. However, a correlation between cooperating teacher and roles established in the present study did not emerge after the data analysis.

*Availability of Technology*

Access to technology did not appear to have an effect on the roles between the pre-service teachers and technology. However, since Smart Boards® were readily available in most classrooms and/or schools, they were used the most often by the pre-service teachers. Those PSTs who used Smart Boards® (n=15) typically used the Smart Board® in conjunction with another technology resource (such as a virtual manipulative) or for display purposes. Those PSTs who used the Smart Board® for display purposes often found themselves classified as the Master role, whereas those who used the Smart Board® in conjunction with other technology tools, particularly virtual manipulatives, often found themselves classified as Master-Servant or Servant. This would support the theory that PSTs who are classified as Master find themselves limited by the technological features of which they are familiar.

*Curriculum Goals*

Curriculum goals had an apparent influence on the roles established in the present study. Those pre-service teachers who tended to choose the objective first and used technology to support the lesson objectives were found at the higher end of the hierarchy (Master-Servant, Servant, and Servant-Partner). Those pre-service teachers who tended to give no explicit statement regarding the role of the objective to the lesson plan were found at the lower end of the hierarchy (in particular, Master). The researcher is hesitant to read too much into this, because the number of participants for each was relatively small, and no direct correlation can be identified. However, it makes sense that those at the higher end of the hierarchy would identify technology as a means of supporting learning, rather than selecting a technology tool for the sake of doing so.

## Evaluation of Technology Tools

### *Criteria Identified by Pre-Service Teachers*

The criteria identified by participants for evaluating the technology tools they used in their lesson plan included the following:

- Software Features: 52.6%
- Motivation: 26.9%
- Learning: 7.7%
- Mathematics. 12.8%

When grouped according to the two organizational categories, Software Features and Motivation (which comprise Surface Features) represent 79% of the criteria identified by the pre-service elementary teachers. Learning and Mathematics (which comprise Content and Instruction) represent 21% of the criteria identified by the pre-service elementary teachers. These findings are consistent with Battey, Kafai, and Franke (2005), who found that pre-service elementary teachers tend to focus on Surface Features rather than Content and Instruction.

Why were participants so focused on the Surface Features rather than Content and Instruction? One possible explanation is that pre-service teachers are focused more on the technology tool itself and less on the learning that results from the use of technology. This theory would certainly be supported by the work of Battey, Kafai, and Franke (2005), who found that pre-service teachers' conceptions of mathematics instruction and technology are not integrated. That is, pre-service elementary teachers may see technology as a standalone activity. If this is true in the present study, then a focus on the technology, rather than the learning, would certainly manifest itself in the criteria used to evaluate the technology tools.

There were no distinct differences between the PDS and PS participants, except that PDS participants focused slightly more on Surface Features (83%) than did PS participants (74%). Since this is not a significant difference, the researcher is hesitant to draw any conclusions about the differences between both groups of participants. However, had interviews with all of the participants been logistically possible, the researcher would have liked to explore this possible difference between both groups.

There is a marked difference in the results of this study as compared to the pilot study (Johnston, 2008). In the present study, Surface Features were identified 79% of the time, and Content and Instruction features were identified 21% of the time. In the pilot study, Surface Features were identified 56% of the time, and Content and Instruction features were identified 44% of the time. However, there were a number of differences in the structure and conditions of the pilot study which may explain the differences in results. First, the participants in the pilot study were not identifying criteria within the context of lesson planning. Second, the participants in the pilot study were told to identify criteria for evaluating virtual manipulatives only, and they evaluated three virtual manipulatives for geometry which were pre-selected by the researcher. Third, the participants in the pilot study were limited to three criteria, whereas in the present study, participants could list as many criteria as they wanted.

Further studies of this type would support (or refute) the researcher's theory that pre-service elementary teachers' content knowledge (CK) and pedagogical content knowledge (PCK) may limit or enhance their evaluations of technology tools. If PSTs have minimal PCK and CK, they do not necessarily take advantage of the affordances of technology tools for mathematical learning. However, since the present study did not attempt to measure either of these factors among the participants, no further claims are made about CK or PCK. Recommendations for further research, with respect to CK and PCK, are made later in this chapter.

*Affordances and Limitations Identified by Pre-Service Teachers*

The affordances and limitations identified by the pre-service teachers were categorized using the codes identified previously, as well as a few others which emerged from the data. These affordances and limitations were:

- Software Features: 51.1%
- Motivation: 18.2%
- Learning: 13.6%
- Mathematics: 10.2%
- Access: 2.3%
- None Identified: 2.3%
- Other: 2.3%

The types of affordances and limitations identified by the pre-service teachers are similar to the types of criteria identified by the pre-service teachers for evaluating the technology tools. Surface Features (which includes Software Features and Motivation) were identified 69% of the time, whereas Content and Instruction (which includes Learning and Mathematics) were identified 25% of the time. These findings are similar to those for the criteria identified by the participants. It is not surprising, then, that the affordances and limitations identified by the participants were close to the criteria for evaluation which were identified by the participants.

These findings would indicate pre-service elementary teachers view technology as standalone and have difficulties integrating technology and learning. These findings also indicate that the pre-service teachers in the present study did not fully take advantage of the affordances of the technology tools for mathematical learning. In addition, their technology pedagogical content knowledge (TPCK) can impact the types of affordances and limitations they identify.

Since Surface Features were identified more frequently than Content and Instruction, I recommend that pre-service elementary teachers have more experiences exploring the affordances and limitations of technology tools in their methods courses. As pre-service teachers discuss issues such as multiple representations, cognitive fidelity, and mathematical fidelity, they begin to see how technology tools can be used with their own future students, and in what context. They also begin to see what steps they need to take to take advantage of the affordances provided by these technology tools and how to overcome the limitations inherent within these tools.

*Lesson Design*

The lesson designs of the pre-service teachers can be represented along a continuum which is concerned with who maintains control of the technology. Those teachers who tended to use technology for display or demonstration purposes were found at the lower end of the role hierarchy (Master, in particular). These pre-service teachers remained in control of the technology. As the continuum progresses, control of the technology gradually shifts to the students. The uses of technology in the lesson design also progressed through productivity, review and practice, and student exploration. As teachers designed lessons which focused on student exploration of a concept, they began to relinquish control and made students responsible for their learning. Pre-service teachers at the Master-Servant, Servant, and Servant-Partner levels of the hierarchy designed lessons where student exploration was the focus of the lesson. Technology tools were utilized to support this lesson design. In this study, the curriculum goals, technology tools, and the lesson design are all characteristics of the roles.

An important point needs to be made here. The roles in the present study are a function of the lesson plan design, the curriculum goals, the technology used, and the pre-service elementary teacher himself. Since these roles are topic dependent, technology dependent, and so on, these roles are subject to change. As these pre-service elementary teachers continue their coursework and learn about more types of technology and design lesson plans for other curricular goals, their roles may or may not change. For example, a teacher in an second grade classroom may be classified as the servant-partner role when using a Smart Board® with her students for exploring fraction concepts. This teacher is familiar with the curriculum goals as well as the technology tools due to prior experience with both. However, the same teacher, if assigned to a middle-school classroom, may be classified as the master role when using Geometer’s Sketchpad® because the tool and the topic may be unfamiliar to her.

## Limitations of the Study

### *Issues of Validity*

The researcher was concerned with possible threats to validity of the results discussed in this chapter. In particular, two specific validity threats, bias and reactivity (Maxwell, 2005), are discussed here. To address researcher bias, the researcher maintained an open mind during the data analysis (in particular, the coding of the data.) Certain coding schema were initially used (i.e., the roles, the criteria) but others were developed during the data analysis. Thus, other roles were identified as a result of this study and were not limited to predefined roles established by the literature. The researcher was not as concerned with reactivity, which is defined as “The influence of the researcher on the setting or individuals studied” (Maxwell, 2005, p. 108) because he did not have any interaction with the participants, other than the initial explanation of the study and distribution of informed consent forms. The course instructor collected all documents and forwarded them to the researcher, and the researcher was not responsible for any of the course instruction. Therefore, reactivity is not a threat to validity in this case.

In addition, the researcher took several steps to test the validity of the conclusions and to identify possible threats to these conclusions (Maxwell, 2005). In particular, triangulation was used as a means of collecting multiple forms of data from the participants. Data included lesson plans, reflection documents, and surveys, Maxwell (2005) notes that “interviews, questionnaires, and document are all vulnerable to self-report bias” (p. 112). Thus, the researcher is cognizant of the fact that his results are based upon self-report.

### *Issues of Generalizability*

The sample size, *n*=35, is relatively small. The results of this study may not necessarily be generalizable to other populations. The results of this study may be unique to this specific population. However, as Maxwell (2005) notes, “external generalizability is often not a critical issue for qualitative studies” (p. 115). Rather, the focus should be on internal generalizability; that is, do the conclusions which result from the study generalize to the group in question as a whole? Based upon the methods used in this study, it is appropriate to answer “yes” to this question.

## Implications for Mathematics Teacher Educators

Methods courses have the potential to engage pre-service teachers in open discussions about the integration of technology in mathematics lessons. When asked, “What impact did the class discussions (led by the instructor) have on the technology tool you selected and how you integrated it into the lesson?”, 24 out of 35 participants (69%) stated that exposure to various tools and discussions of the features of these tools had a direct impact on how they planned their lessons. This finding would suggest that the majority of pre-service teachers are open to the idea of integrating technology in their lesson plans, but that they need guidance in doing so.

This study identified two activities which can be used in methods courses to develop the TPCK of pre-service elementary mathematics teachers. These activities include Reflection Documents (similar to the one used in this study) and interviews with pre-service teachers to discuss their uses of technology in their lesson plans (time permitting, of course). Mathematics teacher educators should consider which activities will best enable their pre-service teachers to appropriately integrate technology into their lesson plans. The researcher recognizes the fact that time is limited during methods coursework and fieldwork experiences. However, reflection documents have the potential to engage pre-service elementary teachers in thoughtful and deliberate reflection upon their reasons for and ways of integrating technology into their mathematics lesson plans. Further research into the effectiveness of such reflection documents would be worthwhile.

In addition, mathematics teacher educators should design activities in which pre-service elementary teachers are actively engaged in exploration of mathematical concepts and supported by technology tools which allow them to do so. If the desired outcome is to move pre-service elementary teachers beyond a surface-level integration of technology in their mathematics lessons, then we need to design our methods coursework around activities which push pre-service teachers beyond demonstration and display types of lessons. Such activities could include: pre-service teachers using virtual geoboards as a means of discovering Pick's Theorem (see Appendix E); pre-service teachers using virtual pan balances to explore methods for solving algebraic equations; pre-service teachers using virtual base-ten blocks to solve addition and subtraction problems involving decimals. In all these cases, the pre-service elementary teachers should work under the premise that they themselves are the students, taking into consideration how they would use these activities with their own future students.

Finally, pre-service elementary teachers find themselves struggling with classroom management issues. As noted in Figure 10, teachers at the Servant role tend to focus on their own control of the technology used by students. As they progress to the Partner role, they begin to recognize the need for students to explore concepts via technology. In doing so, they begin to give up control and ownership of the technology. Since pre-service elementary teachers do struggle with classroom management issues, mathematics teacher educators must be aware of this when designing activities in their coursework. Pre-service elementary teachers must be supported at the fieldwork placement site so that they can overcome this tension which exists.

## Implications for Future Research

The present study was distinct from previous studies involving pre-service mathematics teachers in that it focused on the role and evaluation of technology tools and their influence on lesson design. The roles which emerged during this study may or may not be unique to pre-service elementary mathematics teachers, particularly those enrolled in a career-switcher program. Thus, further research is necessary to determine if similar roles between pre-service elementary mathematics teachers and technology exist among more traditional programs of teacher education.

Further, unlike Goos et al. (2003; 2000), who examined *secondary* mathematics teachers who had been in the classroom for at least a few years, the participants in the present study were pre-service *elementary* teachers. Thus, not only were their experiences limited, so was their mathematical content knowledge. Content knowledge is certainly a factor which is worth examining in future studies, since the instruments did not specifically measure participants' mathematical content knowledge (CK) and pedagogical content knowledge (PCK) in the present study. However, as noted in the researcher's conceptual framework (see Figure 2), and by one of the participants (PDS-2), these are important factors in the integration of technology by pre-service elementary mathematics teachers. Thus, the researcher proposes the following research question for future study, as it was not part of the present study:

- How do mathematical content knowledge (CK) and pedagogical content knowledge (PCK) influence the roles observed between pre-service elementary teachers and technology tools?

Also noteworthy is the fact that this research study was completed during one semester of coursework among the participants. Further research should be conducted to determine if and how the roles which emerged during the present study change as pre-service elementary mathematics teachers gain experience and comfort with using technology. Another research question posed for future study is:

- How do the roles between pre-service elementary mathematics teachers and technology tools change over time?

Finally, the researcher had intended to collect data about the influence of personal beliefs on the roles between pre-service elementary teachers and the technology tools. Specific survey questions and items on the reflection document should be collected to address the issue of personal beliefs.

## Summary

The pre-service elementary teachers in this study identified their math methods course as a primary source of information regarding technology tools for mathematical learning. However, as the present study suggests, just because pre-service elementary teachers are exposed to technology tools in their methods courses doesn’t mean they will integrate technology into their lesson plans or take full advantage of the technology tools. While the present study was not an evaluation of the methods course, the results suggest, nonetheless, that more reflective experiences are needed in the methods course and fieldwork experiences to assist pre-service teachers to better integrate technology.

The Technology Position Statement of the Association of Mathematics Teacher Educators (2006) identifies four outcomes of mathematics teacher education programs. One characteristic of mathematics teacher educators is the ability to:

- understand, by reflecting on how technology affords and constrains student actions and thoughts, when and how use of technology can advance learning and critical thinking, and when it can hinder the mathematical development (p. 2).

This study engaged pre-service elementary teachers in purposeful reflection on the affordances and constraints of the technology tools they used when designing lesson plans for their mathematics methods course. The significance of this research study is that it analyzed the results of one thought-revealing activity, a reflection document, in which pre-service elementary teachers deliberately reflected upon their technology choices. While the majority of the pre-service teachers in this study did not fully take advantage of the technology tools they used, further research is needed to determine what other kinds of activities and experiences will assist pre-service teachers as they develop their knowledge and understanding of technology tools for mathematical learning.

APPENDIX A: PRE-SERVICE ELEMENTARY MATHEMATICS TEACHERS' SELF-REPORTED CONTENT KNOWLEDGE & TECHNOLOGY PREPARATION SURVEY

| | Part I: | **CONTENT** | **KNOWLEDGE** | **AND** | **UNDERSTAD-ING** |
|---|---|---|---|---|---|
| | *Please rate each of the following items in terms of your **content knowledge** and **understanding** of the topic* | Not knowledge-able; No/little understand -ing | Somewhat knowledgeable; partial understanding | Fairly knowledge-able; good understand-ing | Very knowledge-able; Solid Understand-ing |
| 1 | Number and Operations: Number Sense and Place Value | | | | |
| 2 | Number and Operations: Operations with Whole Numbers | | | | |
| 3 | Number and Operations: Operations with Decimals and Fractions | | | | |
| 4 | Number and Operations: Operations with Integers | | | | |
| 5 | Number and Operations: Ratios and Proportions | | | | |
| 6 | Geometry: Shapes and their Properties | | | | |
| 7 | Geometry: Spatial Sense | | | | |
| 8 | Measurement: Area, Perimeter, Volume | | | | |
| 9 | Measurement: Measuring with standard units, conversions within a system, etc. | | | | |
| 10 | Algebra: Patterns and Functions | | | | |
| 11 | Algebra: Sort, classify, and order objects | | | | |
| 12 | Algebra: Graphs and Equations | | | | |
| 13 | Data Analysis and Probability: Graphing Data and Interpreting Graphs | | | | |
| 14 | Data Analysis.Probability: Mean, Median, Mode, | | | | |

| | | | | | |
|---|---|---|---|---|---|
| | Range, etc. | | | | |
| 15 | Data Analysis and Probability: Basic probability concepts | | | | |

| | Part II: | **PREPARATION** | **To Teach** | **With** | **Technology** |
|---|---|---|---|---|---|
| | *Please indicate how **prepared** you feel to teach each one using **technology**.* | Not Adequately Prepared | Somewhat Prepared | Fairly Well Prepared | Very Well Prepared |
| 1 | Number and Operations: Number Sense and Place Value | | | | |
| 2 | Number and Operations: Operations with Whole Numbers | | | | |
| 3 | Number and Operations: Operations with Decimals and Fractions | | | | |
| 4 | Number and Operations: Operations with Integers | | | | |
| 5 | Number and Operations: Ratios and Proportions | | | | |
| 6 | Geometry: Shapes and their Properties | | | | |
| 7 | Geometry: Spatial Sense | | | | |
| 8 | Measurement: Area, Perimeter, Volume | | | | |
| 9 | Measurement: Measuring with standard units, conversions within a system, etc. | | | | |
| 10 | Algebra: Patterns and Functions | | | | |
| 11 | Algebra: Sort, classify, and order objects | | | | |
| 12 | Algebra: Graphs and Equations | | | | |
| 13 | Data Analysis and Probability: Graphing Data and Interpreting Graphs | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 14 | Data Analysis and Probability: Mean, Median, Mode, Range, etc. | | | | | |
| 15 | Data Analysis and Probability: Basic probability concepts | | | | | |

*Part III – Open ended questions.*

For this section, refer to the list of 15 different items from Part II, Preparation to Teach with Technology, found on the previous page.

A. If you had to choose just <u>one</u> of the fifteen items as the one you feel the most prepared to teach with technology – which one would it be? Why?

B. If you had to choose just <u>one</u> of the fifteen items as the one you feel the least prepared to teach with technology– which one would it be? Why?

*Part IV – Personal Uses of Technology*

Rate how often you use each of the following for uses other than academic or employment uses.

| Use of Technology | Multiple Times each Day | Once a Day | Several times per week | Rarely | Never |
|---|---|---|---|---|---|
| Instant Messaging (AOL, Yahoo, MSN) | | | | | |
| Text Messaging (via your cell phone) | | | | | |
| Facebook, Myspace, and other social networks | | | | | |
| Blackberry, PDA, etc. | | | | | |
| Email | | | | | |
| Word Processing | | | | | |

*Part IV – Demographic Information.*

A. Gender _____ Male _____ Female

B. How many college mathematics courses have you completed? Select only one.

_____ None _____ 1 semester _____ 2 semesters
_____ 3 semesters _____ 4 semesters _____ 5 or more semesters

C. To which grade level are you currently assigned? Select only one. (However, if you teach in a multi-grade level, then select those two grade levels.)

_____ K _____ 1 _____ 2 _____ 3 _____ 4
______ 5 _____ 6

D. Where in the lesson planning process (for your technology lesson plan) are you? Check only one.

_____ I have not written my lesson plan yet.

_____ I have begun writing my lesson plan, but it is not complete.

_____ I have written my lesson plan, but I have not taught it yet.

_____ I have written and taught my lesson plan.
[Note this question is for sections 001 and 003 only]

# APPENDIX B: PLANNING FOR INSTRUCTION WITH TECHNOLOGY REFLECTION DOCUMENT

Please note:

- Your reflection on the development of your technology lesson plan is requested. As an ongoing process of improving the methods course, we are conducting a trial project to determine the best way for pre-service teachers to reflect upon the lesson plan writing process.
- Your responses on this document will not be shared with your cooperating teacher (at your fieldwork placement site.)

*Directions:* As you plan your lesson which integrates technology, respond to each of the questions and items below. Please return this document electronically along with the corresponding lesson plan. Simply respond to each of the prompts in the spaces given. You may use this form as a “template” to simply insert your responses.

A. Objective of the Lesson

1. What objective did you select for this lesson?

2. Why did you select this objective?

3. How did your cooperating teacher influence the objective you selected?

4. Were there any other factors which influenced the objective you selected?

5. Describe your knowledge of and comfort with the content of this lesson.

B. Student Characteristics – Think about the students you are teaching.

1. Number of students

    a. Total in class ______

    b. For whom English is not their first language ______

    c. With learning disabilities ______

    d. With other special needs ______

2. How would you describe the ability level of students in your class?

C. Technology Tool

1. Which technology tool did you select?

2. Why did you select this technology tool?

3. What role did the objective play in your selection of the technology tool?

4. How did the abilities and experiences of your students (see part B) impact your use of technology?

5. How did your cooperating teacher influence the technology tool you selected?

6. Were there any other factors which influenced the technology tool you selected (such as computer lab availability, technology in your classroom, etc?)

7. Think about the lesson you planned. Specifically, think of any factors (such as 5 or 6, above) that may have limited your use of technology. How did you compensate for those limitations?

D. Your "Ideal" Lesson

If you didn't have the other influencing factors listed in Part C, what would you have done differently in your lesson plan? Why? Would you change the technology tool, or would you use the same one?

E. Evaluation of Technology Tool

1. What characteristics of the tool influenced your selection? (Note: You do not need to have five. You may have more, or less, depending upon your beliefs.)

| Criterion | Rationale for Inclusion of this Criterion | Evaluation of Technology Tool based on this Criterion |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |

2. What benefits or features do you recognize in this technology tool?

3. What limitations or constraints do you recognize in this technology tool?

4. What representations does this technology tool include? (Remember, certain technology tools allow multiple representations. For example, fractions can have multiple representations.)

F. How will you use this technology tool? Check all that apply.

_____ Teacher tool to represent an idea or concept

_____ Teacher tool to demonstrate a skill or procedure

_____ Student tool to explore mathematics

_____ Student tool for productivity

_____ Student practicing a skill or topic

_____ Other ______________________________

Please explain why you will use the technology in this manner.

G. What impact did the class discussions and activities (led by Dr. Suh) have on the technology tool you selected and how you integrated it into the lesson?

## APPENDIX C: LESSON PLAN FORMAT

I. Objective

   A. Specific objective for lesson

   B. Corresponding Virginia SOL

   C. Corresponding NCTM Standards

II. Materials for Learning Activities

III. Procedures for Learning Activities

   A. Introduction

   B. Instructional Strategies

   C. Summary

   D. Estimated Time

   E. Extensions and Connections

IV. Assessment

V. Differentiation

## APPENDIX D: INTERVIEW PROTOCOL

Note that the following interview questions were tentative and were modified, as necessary, while conducting the actual interviews.

*Introduction: "To begin, I'd like to talk about your third lesson plan, the one in which you used technology."*

A. Walk me through your lesson plan.

B. Describe how you went about selecting your technology tool.

C. How did the lesson go? (Have teachers refer to the reflections written after the lesson was taught.) What went well? What could have been better? (What worked? What didn't?) Why do you feel this way? Did anything "unexpected" happen while using the technology? If so, describe that experience to me.

D. What was the role of communication in this lesson? How did technology support or facilitate communication?

E. Take a look at the criteria you identified prior to teaching the lesson. Would any of them change now that you have taught the lesson? [See Chart from Section E of Appendix B.]

*Introduction: "Next, I want to talk to you about your own experiences with technology."*

F. If you had to write a 2-3 sentence "position statement" about using technology in elementary mathematics, what would that position statement be?

G. Describe how your experiences in the Elementary Education program, which follow, influenced your views on technology:

1. Methods course
2. Fieldwork placement/experiences

H. How have your personal experiences with technology influenced your views of technology?

# APPENDIX E: LESSON PLAN FOR IN-CLASS ACTIVITY TAUGHT BY INSTRUCTOR AND VIDEOTAPED

*Title*
Measuring the Area of Polygons on the Geoboard

*Contributor's Name*
Christopher Johnston

*Grade Level Band*
6-8 (Measurement)

*NCTM Mathematics Standards*
Measurement:
Instructional programs from prekindergarten through grade 12 should enable all students to:
Understand measurable attributes of objects and the units, systems, and processes of measurement

- understand, select, and use units of appropriate size and type to measure perimeter and area

Apply appropriate techniques, tools, and formulas to determine measurements

- select and apply techniques and tools to accurately find length and area to appropriate levels of precision
- develop and use formulas to determine the area of triangles, parallelograms, trapezoids, and develop strategies to find the area of more-complex shapes

Geometry:
Instructional programs from prekindergarten through grade 12 should enable all students to:
Use visualization, spatial reasoning, and geometric modeling to solve problems

- draw geometric objects with specified properties, such as side lengths or angle measures

*Mathematical Topic / Objective of the Lesson/ Key Mathematics Concepts*
Using a virtual geoboard, the student will:

- create polygons given specified properties
- find the area of those polygons
- discover Pick's Theorem, a way of calculating the area of irregular and uncommon polygons
-

*Virtual Manipulative Web Site*
http://nlvm.usu.edu/en/nav/frames_asid_277_g_1_t_3.html

*Materials*
Geoboards and Rubber bands (optional)
Activity Sheet – “What’s My Area?”

*Discussion of the Mathematics*
Using a virtual geoboard, students create polygons based on specified properties. Then, they measure and calculate the areas of those polygons and record the information on the Activity Sheet. Using irregular polygons, students note patterns about the areas of these polygons, and they are led to discovering Pick’s Theorem, a method for calculating the area of polygons on a geoboard.

*Activity / Procedures / Teacher Notes*

General notes: After instruction (for a given numbered section of the lesson plan, starting with #4) has been given, students should work with a partner to complete the activity within that section of the lesson plan. Before moving onto the next activity, the lesson plan calls for a group discussion.

Depending on the ability level of the students, this lesson will take 1-2 periods to complete.

1. Once they have opened the virtual manipulative, students should take time to create simple polygons, such as rectangles, squares, right triangles, etc. Students should determine the area of each (by counting the number of “boxes” or “spaces” within the shape) and have their partner verify the measurements.
2. Students should next create polygons whose areas may be more challenging to determine. For example, students may create pentagons, hexagons, and the like. Students may choose to count the “boxes” and piece half boxes together to make a full box. The areas of some of these shapes may not be so easily determined, so students will want to discover a method for determining the area of any polygon on a geoboard. *[This leads nicely into #3.]*
3. Tell students that they are going to discover the theorem (“rule” that Georg Alexander Pick discovered in 1899. Pick was an artist and mathematician, and he was a friend of Albert Einstein. *[An external reviewer of this lesson suggested this would be a good “hook” for the middle school students.]*
4. Students should next create polygons which have one peg inside the figure and which have varying numbers of pegs on the outside of the shape. Caution students to create polygons which they will be able to measure and calculate the area. (In other words, they should create shapes which they can determine the area simply by counting the number of boxes in an efficient manner.) On the activity sheet, students should record their results. *[If your students are having difficulty completing this section in pairs, you may wish to do this activity as a class. Then, once the activity has been modeled, students should be able to complete the next activities with their partners.]*

*Polygons with One Interior Peg*

| Pegs on the Perimeter (Boundary) | **4** | **5** | **6** | **7** | **8** | **9** | **10** | ***B*** |
|---|---|---|---|---|---|---|---|---|
| Area of Polygon | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 | $B \div 2$ |

Before continuing to the next portion, discuss the results as a class to make sure students are on the right track. Most students should see the pattern fairly quickly and should be able to generalize for when the number of pegs on the boundary is *B*.

5. Students should next create polygons which have no pegs inside the figure and which have varying numbers of pegs on the outside of the shape. Caution students to create polygons which they will be able to measure and calculate the area. On the activity sheet, students should record their results. Discuss how to generalize to "*B*" number of pegs on the boundary. You may need to guide students to this generalization.

*Polygons with No Interior Peg*

| Pegs on the Perimeter (Boundary) | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | ***B*** |
|---|---|---|---|---|---|---|---|---|---|
| Area of Polygon | 0.5 | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | $(B \div 2) - 1$ |

6. Students should next create polygons which have two pegs inside the figure and which have varying numbers of pegs on the outside of the shape. Caution students to create polygons which they will be able to measure and calculate the area. *[Some students may create polygons whose sides form a diagonal within a square on the geobard. The diagonal may not split the square exactly in half.]* On the activity sheet, students should record their results. Discuss how to generalize to "*B*" number of pegs on the boundary. You may need to guide students to determining this after a discussion of various student responses and ideas.

*Polygons with Two Interior Pegs*

| Pegs on the Perimeter (Boundary) | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | ***B*** |
|---|---|---|---|---|---|---|---|---|---|
| Area of Polygon | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 | 5.5 | 6 | $(B \div 2) + 1$ |

7. Give students time to explore creating shapes with three, four, five, etc. pegs inside the figure and alternating the numbers of pegs on the outside of the shape. Ask students to make generalizations or to formulate a rule that will work. As a class, share these generalizations and lead into the next part of the discussion.
8. Project the following table onto the overhead projector (or write on the chalkboard), and record as a class. This part of the lesson should be done as a whole-class, with students focused on the front of the room.

| Pegs inside the figure | 0 | 1 | 2 | 3 | 4 | 5 | *I* |
|---|---|---|---|---|---|---|---|
| Formula for "*B*" Pegs | | | | | | | |

Remind students that "*B*" refers to the number of pegs on the perimeter (boundary) of the polygon. Based on class discussion, observations, and the information in the next paragraph, students should discover that the formula for determining the area of any polygon on a geoboard is as follows: Area = **(*B* ÷ 2) + I – 1**. This is known as Pick's Theorem. (There are other, acceptable versions of this formula, including I + B/2 – 1.

The formula for 0, 1, and 2 have already been discovered in the previous activities. Note that for 0 pegs in the interior, the formula is **(*B* ÷ 2) – 1**. Note that for 1 peg in the interior, the formula is ***B* ÷ 2**. Note that for 2 pegs in the interior, the formula **is (*B* ÷ 2) + 1.** *[If necessary, allow students time to explore 3 pegs in the interior, 4, etc. and note results.]* In each instance, the formula always contains ***B* ÷ 2**; it is the number that is added or subtracted to that value that changes. The number that is subtracted or added to ***B* ÷ 2** is always one less than the number of interior pegs, so that is why *I* is decreased by 1.

*Student Assessment*

Students can return to their initial polygons and use Pick's Theorem to determine whether or not their initial area calculations were correct.

The teacher can project polygons on the overhead projector and/or television monitor and students can determine the area of each, using Pick's Theorem.

*Student Work/ Examples of What Students Have Done During this Lesson / Comments on What to Expect from Students*

- When creating polygons on the Activity Sheet, students may have trouble creating some of the required shapes. If this is the case, encourage them to create the ones they can even if they go out of order.
- On Part II of the Activity Sheet, students may give various rules or "formulas" for generalizing *B*. Some examples include *B* ÷ 2, *B* ÷ 0.5, *B* ÷ 2.5. The teacher may need to guide students into the rule of taking half of *B* and then subtracting one.

This is also a good opportunity to review the concept of dividing by two giving the same result as multiplying by a half.

- On Part III, it is especially helpful for some students to go out of order. They can create the bigger shapes first, and then generalize the pattern discovered to create the smaller shapes.

*Extensions / Connections*

See attached Activity Sheet: "What's My Area?"

Extension: Students can use Microsoft Excel® or another spreadsheet program to create a table in which another user can enter the number of pegs on the inside of a polygon, as well as the number of pegs on the exterior/perimeter of the polygon. By programming the formula (for Pick's Theorem), the spreadsheet would automatically calculate the area for the user.

*References*

http://homepage.mac.com/efithian/Geometry/Activity-03.html

Name ____________________________ Date ____________

Activity Sheet – "What's My Area?"

I. Create polygons on your geoboard which have one peg inside the figure and which have the following numbers of pegs on the outside (boundary.) Record the area of each polygon in the chart below.

*Polygons with One Interior Peg*

| Pegs on the Perimeter (Boundary) | **4** | **5** | **6** | **7** | **8** | **9** | **10** | ***B*** |
|---|---|---|---|---|---|---|---|---|
| Area of Polygon | | | | | | | | |

*B* represents any number of pegs on the boundary.

II. Create polygons on your geoboard which have no pegs inside the figure and which have the following numbers of pegs on the outside (boundary.) Record the area of each polygon in the chart below.

*Polygons with No Interior Pegs*

| Pegs on the Perimeter (Boundary) | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | ***B*** |
|---|---|---|---|---|---|---|---|---|---|
| Area of Polygon | | | | | | | | | |

*B* represents any number of pegs on the boundary.

III. Create polygons on your geoboard which have two pegs inside the figure and which have the following numbers of pegs on the outside (boundary.) Record the area of each polygon in the chart below.

*Polygons with Two Interior Pegs*

| Pegs on the Perimeter (Boundary) | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | ***B*** |
|---|---|---|---|---|---|---|---|---|---|
| Area of Polygon | | | | | | | | | |

*B* represents any number of pegs on the boundary.

## APPENDIX F: TIMELINE FOR PROJECT

| Date | Activity |
|---|---|
| September, 2008 | Submitted HSRB Application: Office of Research Subject Protections |
| September, 2008 | Designed technology lesson plan and activity for methods course (Instructor and researcher worked together) |
| October 21/22, 2008 | Researcher visited Section 1 (Oct. 21) & 3 (Oct. 22) to explain study<br>Researcher distributed and collected informed consent forms |
| October 29, 2008 | Instructor conducted in-class activity with Section 3<br>Researcher videotaped class session |
| November 4, 2008 | Instructor conducted in-class activity with Section 1<br>Researcher videotaped class session |
| November 5, 2008 | Electronic survey sent to participants |
| Oct. 29 – Dec. 10, 2008 | Participants designed and taught their lesson plans with technology Section 3 |
| Nov. 4 – Dec. 16, 2008 | Participants designed and taught their lesson plans with technology Section 1 |
| December 10, 2008 | Deadline for participants to email lesson plan and accompanying instrument to instructor and researcher (Section 3) |
| December 16, 2008 | Deadline for participants to email lesson plan and accompanying instrument to instructor and researcher (Section 1) |
| January, 2009 | Researcher conducted interviews with selected participants |

APPENDIX G: EXAMPLES OF CODING OF PARTICIPANTS' CRITERIA (RESEARCH QUESTION 3A)

*Software Features*

PDS-9

| Criterion | Rationale for Inclusion of this Criterion | Evaluation of Technology Tool based on this Criterion |
|---|---|---|
| Easiness of use | I didn't want to have it crash on me during the lesson. | Have been using them for years now, so it was quite easy! |

*Motivation*

PDS-17

| Criterion | Rationale for Inclusion of this Criterion | Evaluation of Technology Tool based on this Criterion |
|---|---|---|
| Game | It makes learning about fractions fun | Great |

*Mathematics*

PDS-4

| Criterion | Rationale for Inclusion of this Criterion | Evaluation of Technology Tool based on this Criterion |
|---|---|---|
| Showed decimal regrouping | Students need to learn this concept | Great |

*Learning*

PDS-8

| Criterion | Rationale for Inclusion of this Criterion | Evaluation of Technology Tool based on this Criterion |
|---|---|---|
| Meets objective requirements. | The tool needs to support the objective in order to be of use in the lesson. | This tool met this purpose very well. |

REFERENCES

REFERENCES

Association of Mathematics Teacher Educators. (2006). Preparing teachers to use technology to enhance the learning of mathematics: A position statement of the Association of Mathematics Teacher Educators. Retrieved June 14, 2008, from www.amte.net.

Battey, D., Kafai, Y., & Franke, M. (2005). Evaluation of mathematical inquiry in commercial rational number software. In C. Vrasidas & G. Glass (Eds.), *Preparing teachers to teach with technology* (pp. 241-256). Greenwich, CT: Information Age Publishing.

Chinnappan, M. (2000). Preservice teachers' understanding and representation of fractions in a JavaBars environment. *Mathematics Education Research Journal, 12*, 234-253.

Creswell, J. W. (2005). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (2nd ed.). Upper Saddle River, NJ: Merrill Prentice Hall.

DaPonte, J. P., Oliveira, H., & Varandas, J. M. (2002). Development of pre-service mathematics teachers' professional knowledge and identity in working with information and communication technology. *Journal of Mathematics Teacher Education, 5*, 93-115.

Doerr, H. M., & Zangor, R. (2000). Creating meaning for and with the graphing calculator. *Educational Studies in Mathematics, 41*, 143-163.

Duhaney, D. C. (2001). Teacher education: Preparing teachers to integrate technology. *International Journal of Instructional Media, 28*, 23-30.

Fey, J. T. (1989). Technology and mathematics education: A survey of recent developments and important problems. *Educational Studies in Mathematics,* 20, 237-272.

Flores, A., Knaupp, J. E., Middleton, J. A., & Staley, F. A. (2002). Integration of technology, science, and mathematics in the middle grades: A teacher preparation program. *Contemporary Issues in Technology and Teacher Education, 2*. Available http://www.citejournal.org/vol2/iss1/mathematics/article1.cfm.

Garofalo, J., Drier, H., Harper, S., Timmerman, M. A., & Shockey, T. (2000). Promoting appropriate uses of technology in mathematics teacher preparation. *Contemporary Issues in Technology and Technology Education, 1*, 66-88.

Glesne, C. (2005). *Becoming qualitative researchers: An introduction* (3rd ed.). Boston, MA: Pearson Allyn & Bacon.

Goos, M. (2005). A sociocultural analysis of the development of pre-service and beginning teachers' pedagogical identities as users of technology. *Journal of Mathematics Teacher Education, 8*, 35-59.

Goos, M., Galbraith, P., Renshaw, P., & Geiger, V. (2003). Perspectives on technology mediated learning in secondary school mathematics classrooms. *Journal of Mathematical Behavior, 22*, 73-89.

Goos, M., Galbraith, P., Renshaw, P., & Geiger, V. (2000). Reshaping teacher and student roles in technology-enriched classrooms. *Mathematics Education Research Journal, 12*, 303-320.

Handal, B., & Herrington, A. (2003). Re-examining categories of computer-based learning in mathematics education. *Contemporary Issues in Technology and Teacher Education, 3*, 275-287.

Hazzan, O. (2000). Attitudes of prospective high school mathematics teachers towards integrating information technologies into their future teaching. *Proceedings of the Society for Information Technology and Teacher Education, 11*, 1582-1587.

Hazzan, O. (2003). Prospective high school mathematics teachers' attitudes toward integrating computers in their future teaching. *Journal of Research on Technology in Education, 35*, 213-225.

Johnston, C. J. (2008). Pre-service teachers' criteria for evaluating technology tools for mathematics learning. Unpublished doctoral pilot study, George Mason University.

Jonassen, D. H., Carr, C., & Yueh, H. (1998). Computers as mindtools for engaging learners in critical thinking. *TechTrends, 43*(2), 24-32.

Kafai, Y., Franke, M., & Battey, D. (2002). Educational software reviews under investigation. *Education, Communication & Information, 2*, 163-180.

Kaput, J. J., & Thompson, P. W. (1994). Technology in mathematics education research: The first 25 years in the JRME. *Journal for Research in Mathematics Education, 25*, 676-684.

Kastberg, S., & Leatham, K. (2005). Research on graphing calculators at the secondary level: Implications for mathematics teacher education. *Contemporary Issues in Technology and Teacher Education, 5*, 25-37.

Kersaint, G. (2007). Toward technology integration in mathematics education: A technology-integration course planning assignment. *Contemporary Issues in Technology and Teacher Education, 7*, 256-278.

Kersaint, G., Horton, B., Stohl, H., & Garofalo, J. (2003). Technology beliefs and practices of mathematics education faculty. *Journal of Technology and Teacher Education, 11*, 567-595.

Kurz, T., & Middleton, J. A. (2006). Using a functional approach to change preservice teachers' understanding of mathematics software. *Journal of Research on Technology in Education, 39*, 45-65.

Kurz, T. L., Middleton, J. A., & Yanik, H. B. (2005). A taxonomy of software for mathematics education. *Contemporary Issues in Technology and Teacher Education, 5*, 123-137.

Kurz, T., Middleton, J., & Yanik, H. B. (2004). Preservice teachers' conceptions of mathematics-based software. *Proceedings of the International Group for the Psychology of Mathematics Education, 28*, 313-320.

Li, Q. (2005). Infusing technology into a mathematics methods course: Any impact? *Educational Research, 47*, 217-233.

Maxwell, J. A. (2005). *Qualitative research design: An interactive approach* (2nd ed.). Thousand Oaks, CA: Sage.

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

Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record, 108*, 1017-1054.

Monaghan, J. (2004). Teachers' activities in technology-based mathematics lesson. *International Journal of Computers for Mathematical Learning, 9*, 327-357.

Moyer, P. S., Bolyard, J. J., & Spikell, M. A. (2002). What are virtual manipulatives? *Teaching Children Mathematics*, *8*, 372-377.

National Council of Teachers of Mathematics. (2008). Illuminations. http://illuminations.nctm.org.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics*. Reston, VA: Author.

National Council for Accreditation of Teacher Education & National Council of Teachers of Mathematics. (2003). Program standards for programs for initial preparation of mathematics teachers. Retrieved April 1, 2007, from http://www.nctm.org/uploadedFiles/Math_Standards/NCTMELEMStandards(1).pdf.

Niess, M. L. (2005). Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge. *Teaching and Teacher Education, 21*, 509-523.

Niess, M. L., Suharwoto, G., Lee, K., & Sadri, P. (2006, April). Guiding inservice mathematics teachers in developing TPCK. Paper presented at the annual meeting of the American Education Research Association, San Francisco, CA.

Patahuddin, S. M. (2008). Use of the internet for teacher professional development and for teaching mathematics: Supports and inhibitors. In M. Goos, R. Brown, & K. Makar (Eds.), *Proceedings of the 31st Annual Conference of the Mathematics Education Research Group of Australasia*, 399-405.

Ross, J. A., Hogaboam-Gray, A., McDougall, D., & Bruce, C. (2002). The contribution of technology to the implementation of mathematics education reform: Case studies of grade 1-3 teaching. *Journal of Educational Computing Research, 26*, 87-104.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, *15*(2), 4-14.

Stein, M. K., Grover, B. W., & Henningsen, M. (1996). Building student capacity for mathematical thinking and reasoning: An analysis of mathematical tasks used in reform classrooms. *American Educational Research Journal, 33*, 455-488.

Utah State University. (2007). National Library of Virtual Manipulatives. http://nlvm.usu.edu.

Zbiek, R., Heid, M. K., Blume, G. W., & Dick, T. P. (2007). Research on technology in mathematics education: A perspective of constructs. In F. K. Lester (Ed.), *Second* *handbook of research on mathematics teaching and learning* (pp. 1169-1206). Reston, VA: National Council of Teachers of Mathematics.

# CURRICULUM VITAE

Christopher J. Johnston was born on November 16, 1976 in Flushing, NY. He was raised on Long Island (NY), where he lived for 18 years. In 1998, he earned a Bachelor of Arts in Elementary Education with a specialization in Mathematics at Concordia University, River Forest, IL. In 2002, he earned a Master of Arts in Computer Science and Mathematics Education at Concordia University, River Forest, IL. For eight years, Christopher taught middle school math at two different private schools, one in Chicago, IL, and one in Falls Church, VA.

In 2002, he enrolled in the Ph.D. in Education program at George Mason University. He has worked as a graduate lecturer and a graduate research assistant at George Mason University. In addition to his graduate work, Christopher has served as the lead consultant for Illuminations, a project of the National Council of Teachers of Mathematics. He is an active member of the Technology Committee of the Association of Mathematics Teacher Educators, and he regularly attends and presents at conferences. Christopher has also served as the Managing Editor of the *Journal of Technology and Teacher Education.*